A PROCESS TO IMPROVE COMPUTER-SUPPORTED COLLABORATIVE WORK THROUGH THE CONSTRUCTION, MONITORING AND ASSISTANCE OF SHARED UNDERSTANDING IN PROBLEM-SOLVING ACTIVITIES

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Tesis de Doctorado en Ciencias de la Electrónica

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Tesis presentada a la Facultad de Ingeniería Electrónica y Telecomunicaciones de la Universidad del Cauca para la obtención del título de Doctora en Ciencias de la Electrónica

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I want to dedicate this thesis, first to God, who gave me the strength to make everything possible, to my family, my parents, Anamabel and Daniel, who have been my greatest motivation to move forward, they always gave me their support and unconditional love. To Valentina, my little sister, who has been my greatest pride and who has always inspired me to be better. Thanks to them, for always being there for me, all of them were an essential part of this achievement and were the main protagonists of this dream.

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Resumen

La dificultad en la interacción social genera bajos niveles de entendimiento entre los participantes sobre lo que deben hacer y sobre el problema a resolver, lo que resulta en el principal problema del trabajo colaborativo, la difícil construcción de una verdadera colaboración. Por lo tanto, en la búsqueda de mejorar este trabajo colaborativo e incentivar esta colaboración, es necesario implementar estrategias que promuevan la construcción de un entendimiento compartido, para obtener mejores resultados grupales, los cuales se obtienen gracias a la consecuencia de una mejor comunicación, y coordinación entre los participantes. Sin embargo, construirlo se convierte en un reto debido a los factores que influyen en él y a lo poco que se conoce sobre su construcción. En este sentido, para mejorar el trabajo colaborativo, como resultado de un proceso de investigación, se propone el proceso THUNDERS, el cual ha sido construido utilizando el enfoque de Ingeniería de Métodos Situacionales, como resultado final, se obtiene la especificación de un proceso en SPEM 2.0, a dos niveles, conceptual (define los elementos y la forma de ejecutar el proceso colaborativo) y tecnológico (herramientas de soporte para dicha ejecución), para diseñar, ejecutar y validar una actividad de resolución de problemas colaborativa, con formación de grupos heterogéneos, que proporciona una secuencia de fases, actividades, tareas y pasos, bien definidos y una clara especificación de los productos de trabajo. Además de ser un proceso que se basa en la construcción de un entendimiento compartido en cada uno de sus elementos, también proporciona elementos de seguimiento y asistencia. THUNDERS fue además sometido a un conjunto de experiencias empíricas de validación en diferentes etapas de la investigación y en diferentes contextos, que permitieron construir el proceso de manera iterativa e incremental. Una primera validación, permitió analizar 2 fases, el Pre-Proceso, y el Proceso, a través de un experimento se obtuvo que esta versión era factible y útil, sin embargo, su aplicación generaba una alta carga cognitiva y no era fácil de aplicar, y un estudio exploratorio donde se obtuvo que era un proceso que promovía y mejoraba la comprensión compartida en aquellos grupos que aplicaban el proceso. Una nueva versión del proceso fue validada en una segunda iteración, por expertos en ingeniería de software y de procesos, que validaron la sintaxis y la semántica del proceso, de forma que se identificaron algunos errores en la especificación del proceso, donde se corrigieron los errores encontrados y se creó una nueva versión, la cual se denominó THUNDERS, con la que se realizó un experimento y se pudo determinar que THUNDERS es completo y útil. Sin embargo, sigue siendo un proceso largo, difícil de usar y, cuando se utiliza, genera una alta carga cognitiva. Teniendo en cuenta los resultados de la validación anterior, se generó una nueva versión, la cual se sometió a la validación de expertos en temas de colaboración, con el fin de analizar aspectos colaborativos y seleccionar las tareas que son o no obligatorias en la ejecución del proceso, además, se realizó una validación con AVISPA-Método para realizar un análisis visual del modelo de proceso. Con los resultados, se realizaron correcciones y actualizaciones, generando una nueva versión, la cual fue validada en un caso de estudio y como resultado se determinó que el uso de THUNDERS sí mejora considerablemente el trabajo colaborativo desde varios aspectos como la colaboración, los mejores resultados obtenidos, y la mejor satisfacción por parte de los participantes, sin embargo, aún necesita un soporte tecnológico que le permita ayudar en la ejecución completa, e incluso ser más fácil y ligero de usar. Finalmente, se pudo determinar que esta investigación aporta en muchas líneas de interés desde diferentes aspectos, los cuales aun siguen siendo necesarios de mayor investigación para mejorar el proceso, validarlo en otros contextos y obtener mejores propuestas.

Palabras Clave: Trabajo colaborativo soportado por computador, Entendimiento compartido, Mejora de procesos, Actividades de resolución de problemas, Agrupación heterogénea.

Abstract

The difficulty in social interaction generates low levels of understanding among participants about what to do and about the problem to be solved, which results in the main problem of collaborative work, the difficult construction of true collaboration. Therefore, in the search to improve this collaborative work and encourage this collaboration, it is necessary to implement strategies that promote the construction of a shared understanding, in order to obtain better group results, which are obtained thanks to the consequence of better communication and coordination among the participants. However, building it becomes a challenge due to the factors that influence it and the little that is known about its construction. In this sense, to improve collaborative work, as a result of a research process, the THUNDERS process is proposed, which has been built using the approach of Situational Method Engineering, as a final result, the specification of a process in SPEM 2. 0, at two levels, conceptual (defines the elements and the way to execute the collaborative process) and technological (support tools for such execution), to design, execute and validate a collaborative problem-solving activity, with heterogeneous group formation, which provides a sequence of phases, activities, tasks, and steps, well defined and a clear specification of the work products. In addition to being a process that is based on the construction of a shared understanding in each of its elements, it also provides elements of follow-up and assistance. THUNDERS was also subjected to a set of empirical validation experiences at different stages of the research and in different contexts, which allowed the process to be built in an iterative and incremental manner. A first validation allowed for analyzing 2 phases, the Pre-Process and the Process, through an experiment it was obtained that this version was feasible and useful, however, its application generated a high cognitive load and was not easy to apply, and an exploratory study where it was obtained that it was a process that promoted and improved the shared understanding in those groups that applied the process. A new version of the process was validated in a second iteration, by experts in software and process engineering, who validated the syntax and semantics of the process, so that some errors were identified in the specification of the process, where the errors found were corrected and a new version was created, which was called THUNDERS, with which an experiment was conducted, and it was determined that THUNDERS is complete and useful. However, it is still time-consuming, difficult to use and, when used, generates a high cognitive load. Considering the results of the previous validation, a new version was generated, which was submitted to the validation of experts in collaboration issues, in order to analyze collaborative aspects and select the tasks that are or are not mandatory in the execution of the process, in addition, a validation was performed with AVISPA-Method to perform a visual analysis of the process model. With the results, corrections and updates were made, generating a new version, which was validated in a case study, and as a result, it was determined that the use of THUNDERS does improve considerably the collaborative work from several aspects such as collaboration, better results obtained, and better satisfaction on the part of the participants, however, it still needs technological support that allows it to help in the complete execution, and even be easier and lighter to use. Finally, it was determined that this research contributes to many lines of interest from different aspects, which are still in need of further research to improve the process, validate it in other contexts and obtain better proposals.

Keywords: Computer-supported collaborative work, Shared understanding, Process improvement, Problem-solving activities, and Heterogeneous grouping.

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Chapter 1

INTRODUCTION

1.1 Overview

The following sessions of this chapter describe the motivation for this project, which arises mainly from the research aspect of collaborative engineering and how software engineering supports the generation of a proposed solution to the main research problem identified. This motivation is reflected in the main problem of Computer-Supported Collaborative Work (CSCW), which is based on the difficulty of building a true collaboration, and therefore, in the need to have a formal step by step that guides this construction, from the design, execution and finally, the validation of the fulfillment of the problem and the evaluation of the performance of the participants; It is here where software engineering provides methods and concepts, which were used to support the definition of the necessary elements for the specification of a process that satisfies the main requirements to be considered in each of the phases of the collaborative process. This chapter also shows the objectives and hypotheses, as well as the research method followed for the development of the project and, finally, the structure of this final thesis document. The sections of this chapter are summarized in the following image (See Figure 1.1).

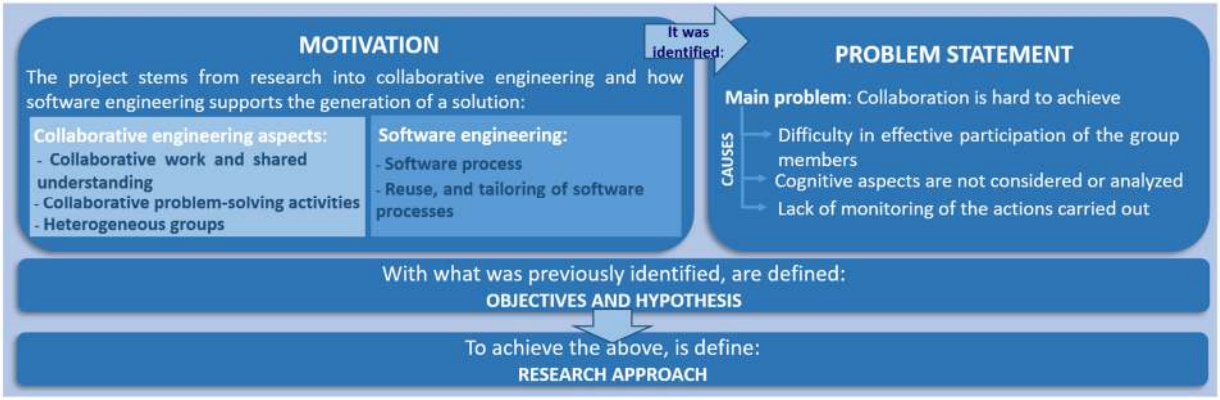


Figure 1.1 Sections presented in this chapter

1.2 Motivation

Each person who belongs to a group and who will perform a collaborative activity together, participates in it, with their strengths, weaknesses, preferences, forms of communication, personal objectives, and diversity in aspects such as: age, gender, personal characteristics, learning styles, experience, among others (Kip & Schaefer, 2014). All these elements, when not handled correctly, can fundamentally affect the way of working, generating communication difficulties and causing the group not to agree on the interpretation of what they are going to do, the tasks to be performed, how they will work together and what the problem of the activity is, that is to say, these problems, refer to problems corresponding to the non-construction of shared understanding, and as an additional consequence, little motivation will be generated among the group, triggering low levels of collaboration and giving results that are not as expected (Hsieh, 2006), which leads to a need to build in early stages the shared understanding (Bedwell, et al., 2012). However, according to Bittner and Leimeister (2014), little is known about what leads to shared understanding, moreover, those who want to engage in collaborative activity need guidance on how to deliberately and repeatedly evoke processes to achieve such shared understanding and, consequently, achieve better collaboration.

The above was the incentive for the development of this project, considering that there is the main aspect of research to analyze, collaborative engineering, and how from software engineering is supported for the structuring of a proposal to solve the problem addressed in this research project, it is for that reason that from these two aspects were analyzed in detail in the following sections and subsequently served to determine the problem statement.

1.2.1 Collaboration engineering aspects

1.2.1.1 Collaborative work and shared understanding

Today, some of the most important decisions in organizations and the solution to complex problems are faced by groups of experts in specific subjects and from different areas who contribute to these actions (Eseryel, Ganesan, & Edmonds, 2002). Furthermore, the rapid growth of information and communication technologies, the complex requirements of projects, and the work between geographically dispersed people, are generating new ways of working and modifying different practices in people's daily lives. On this transformation, there is a progressive trend towards collaboration to achieve a common goal, where work is organized in groups and each of the members interacts with the rest to obtain greater productivity with better results (Centro InterUniversitario de desarrollo CINDA, 2000). However, working collaboratively is not an easy task; it is necessary to go beyond the mere structuring of activities, the design of technological applications, organizing groups and telling them to collaborate (Johnson, Johnson, & Smith, 2013) (Rummel & Spada, 2005). A deeper approach must be taken to ensure collaboration between work groups through the analysis of some external factors such as: people, the formation of the groups and their respective roles, the design and execution of the collaborative activity, and the technological infrastructure, among others (Scagnoli N. , 2005). In this sense, some research has conducted activities to improve collaboration in the learning context (Collazos C. , 2014), (Collazos, Muñoz Arteaga, & Hernández, 2014), (Agredo Delgado, Collazos, & Paderewski, 2016), (Agredo Delgado, Collazos, Fardoun, & Safa, 2017). On the other hand, approaches have also been developed to improve different aspects of collaborative work (Lowry, Albrech, Lee, & Nunamaker, 2002), (Lowry & Nunamaker, 2003), (Garcia, Molina, Martınez, & Gonzalez, 2008), (DeFranco, Neill, & Clariana, 2011), (Leeann, 2015), (Barker Scott, 2017). These and other works have in common that they pay particular attention to the processes followed and the tools provided to aid communication and interaction among group members; but the critical cognitive aspects that ensure that the groups effectively and efficiently achieve a common goal in ways that enhance collaborative work, are often absent (DeFranco, Neill, & Clariana, 2011). One of these cognitive processes is Shared Understanding (SU), whose existence in the collaborative work process among all the actors involved is a prerequisite for its successful implementation (Oppl, 2017), since groups engaged in collaborative work must have some common knowledge and understanding, which functions as a joint baseline, in order to be able to work productively (Christiane Bittner & Leimeister, 2013).

In general terms, SU refers to the degree to which people agree on the issues, the interpretation of a concept with respect to an object of understanding, is when group members share a perspective (mutual agreement) or can act in a coordinated manner (Van den Bossche, Gijselaers, Segers, Woltjer, & Kirschner, 2011). The SU of the task is an important determinant of performance as well as a challenge in heterogeneous groups (Christiane Bittner & Leimeister, 2013) as group members might be using the same words for different concepts or different words for the same concepts without realizing it (de Vreede, Briggs, & Massey, 2009). Differences in the meaning assigned to key concepts or information can interfere with the productivity of collaborative work if they are not clarified from the beginning (Kleinsmann, Bujis, & Valkenburg, 2010), (Mohammed, Ferzandi, & Hamilton, 2010).

1.2.1.2 Collaborative problem-solving activities

In problem-solving activities, collaboration is an essential skill in organizations because many of the problems facing the modern world require teams to integrate their knowledge, experience, skills, and abilities with other members to obtain better solutions and results (Barron, 2000). Considering further, that the increasing complexity of society requires a collaborative approach to problem-solving, it can be deduced that for collaboration to occur, there must be a SU of the problem being solved (Mohammed & Ringseis, 2001), which is an important determinant of the performance of collaborative groups, allowing them to coordinate to work better around the problem to be solved (Langan-Fox, Anglim, & Wilson, 2004), (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). According to Hansen (2018), every problem-solving process starts from identifying the problem and understanding it, so it is important to have elements that enhance this understanding with the group and its approach. After this understanding, the team must evaluate possible courses of action and choose the best way to address the problem, this requires a deep understanding of the team and its strengths (Beecroft, Duffy, & Moran, 2003). However, getting them to coordinate, to all understand the tasks and concepts to be used, to work together effectively requires some work, in addition the literature review is rather sparse when it comes to improving collaborative problem solving by focusing on building the SU (Quashigah, 2017).

1.2.1.3 Heterogeneous groups

A group is a community of collaborating participants, which may be very small or very large, perhaps close-knit, sharing goals, tasks, common knowledge, and preferences, or it may be very amorphous, unaware of the other members and with no explicit shared goals (Ellis & Wainer, 1999). In many situations, when group members lose the motivation to work collaboratively, they do not see the benefits of working with others, and it is not possible to generate contribution in the pursuit of achieving the common purpose (Slavin, 1996), in this way, in some collaborative groups, because they do not understand the task, the execution is not efficient, and the task becomes unmotivating (Barron, 2003). On the other hand, research on group work has shown that collaboration is critical to organizational productivity, as many tasks exceed the cognitive abilities of any individual and therefore depend on the collaboration of heterogeneous and interdisciplinary groups (Fischer, 2000), (Langan-Fox, Anglim, & Wilson, 2004). Previous research shows that, under certain conditions, heterogeneous groups can perform better on complex tasks than homogeneous groups (Bowers, Pharmer, & Salas, 2000), (Wegge, Roth, Neubach, Schmidt, & Kanfer, 2008). For this reason, it is important to focus on heterogeneous groups with three to five members to make interactions easier to describe (Ellis & Wainer, 1999), in addition to allowing an odd number to agree to vote, considering that research points to positive effects on achievement, self-esteem, intergroup relations, and greater acceptance of group members (Slavin, 1991). The idea of collaborative heterogeneous groups is to design work that requires the multiple capabilities of the group members to solve, manage and complete a complex task that has the uncertainty of a challenge (Cohen & Lotan, 2014) and needs the contributions of all group members (Lotan, Swanson, & LeTendre, 1992).

According to the analysis from the aspect of collaborative engineering, it is possible to identify the need to support in a detailed and guided way, the execution of collaborative work in each of its phases, especially in the achievement of shared understanding in problem-solving activities, which is a type of collaborative activities that by their nature require the expertise of different types of participant profiles, which when forming heterogeneous groups, to solve a problem, may have more communication problems and therefore need support to coordinate and thus achieve collaboration.

1.2.2 Software engineering

1.2.2.1 Software process

A disciplined software process is one of the best mechanisms to manage and control projects in the construction of different software products, increasing the productivity and quality of the actions performed in them (Xu, 2005). In this sense, according to the literature, there is a lack of disciplined approaches for collaborative work that determine a guide to have what and how to achieve the SU from the moment the activity is designed, executed, and the objectives are validated, which makes its repeated construction difficult (Werner, Shi Li, Ernst, & Damian, 2020) (Windeler, Maruping, Robert, & Riemenschneider, 2015) (Bittner & Leimeister, 2014). Considering this, from this project it was considered viable to use the concept and the benefits of a formal and disciplined process to support the execution of the different activities, in the context of collaboration, in order to support the construction of the SU, providing a process that guides the work in a collaborative activity in which the objectives are sought, where all group members must understand why they are doing what they do, how they plan to do it and what they have done so that they can be on the same page and thus obtain better results (Kleinsmann, Valkenburg, & Buijs, 2007).

1.2.2.2 Reuse, and tailoring of software processes

There are different contexts in which collaborative activities can be carried out, and in each of them, it will be necessary to define a specific process that suits it. Thus, the process must provide adaptation mechanisms based on the management of the process assets that are part of its definition, and depending on the context, some of them may be common and others will need a degree of adaptation according to the characteristics analyzed (Whitehead, 2007). Those process assets that are common will need to apply reuse, using their description to derive other processes (Hollenbach & Frakes, 1996). And those processes that require modification will need to apply the adaptation of those assets, adjusting their definition and/or particularizing the terms of their general description to derive alternative processes, satisfying specific characteristics (Armbrust, Ebel, Hammerschal, Münch, & Thoma, 2008), (Jacobson, Booch, & Rumbaugh, 1999), (Humphrey W. S., 1989).

According to this, process line engineering is an approach to making process adaptation; where a Software Process Line (SPrL) allows obtaining a set of processes in a particular domain or for a particular purpose, with common characteristics and built on the basis of common and reusable process assets (Washizaki, 2006) (Armbrust, et al., 2009). Considering this, in the field of collaborative work, it is necessary to achieve common objectives that can be obtained in different contexts (education, enterprise, health, business, software product development, among others), where each one of these, according to its characteristics, requires different elements, activities, tasks, steps, deliverables, etc., that must be executed or taken into account, to carry out a collaborative activity (Whitehead, 2007) (Werner, 2021), so it is necessary to derive specific processes that respond to specific situations for each context and that are as light or as large according to the needs of the context and this is where the motivation to include elements of software engineering is born and specifically of adaptation and reuse of processes to generate processes according to the required needs, and that allow the specification of the requested process.

1.3 Problem statement

In group work, achieving collaboration improves the way a team works together and solves a specific problem, leading to greater innovation of the results obtained, efficient processes, the achievement of the proposed objectives, better communication, and therefore the success of the collaborative activity (Hoegl & Gemuenden, 2001). However, working collaboratively is not an easy task, one of the main problems of collaborative work is that collaboration does not occur as easily as one might expect (Rummel & Spada, 2005), being difficult to achieve, guarantee or even predict (Grudin, 1988). This is why to ensure effective collaboration and, consequently, to improve collaborative work, a deeper analysis of external factors that affect the achievement of such collaboration is necessary (Persico, Pozzi, & Sarti, 2009) (Scagnoli N. , 2005).

When a collaborative activity is required, normally, the activity to be solved is defined, the groups are formed, often randomly, a support software tool is defined and/or selected and the necessary material is defined (Hoegl & Gemuenden, 2001). In this sense, an example of collaborative work and its main problem is shown (See Figure 1.2), where the collaborative activity is based on the fact that the group must perform the software development process of a shopping cart. For this, initially, the activity to be executed is socialized, with the group already formed (where the roles of the project manager, two developers, an analyst, and the architect are determined), the group begins to work, on one side, there is the one who takes the floor, many times trying to impose his ideas, on the other side, the majority seems to listen, but some of them may be totally distracted by their own problems, and others with low motivation to execute the activity are doing other things, others are analyzing what they hear according to their perceptions, where each one understands the need of the problem and what they do according to their level of experience, knowledge and contribute ideas according to this. Thus, generating different understandings of the issues being worked on, where each one acts according to their perceived ideals and this may not coincide with what the others are doing, thus demonstrating a lack of common understanding among the participants. However, with this panorama of the participants, where there is no participation of all and some of them are not in tune with all, the activity is solved with those who really participate in the development it. In the end, a software product is generated, a shopping cart to be used and managed from a computer, which is delivered to the customer, who determines that the product was desired in a mobile version and with different features than those delivered. Here many problems associated with different factors that have affected the collaborative activity can be observed, the main problem is determined as the difficulty of obtaining the collaboration of all participants that allows from their contribution, experience, and knowledge to obtain adequate results. According to this, among many causes that according to literature and experience have been identified (Kip & Schaefer, 2014), this project will focus mainly on: the difficulty in the effective participation of the group members, the non-consideration and analyze of those cognitive aspects that are critical and necessary for the participants to collaborate, for this project will be studied mainly the shared understanding, and finally, the lack of monitoring of the actions performed so that these are modified or corrected in time and the work can be directed and obtain the expected results.

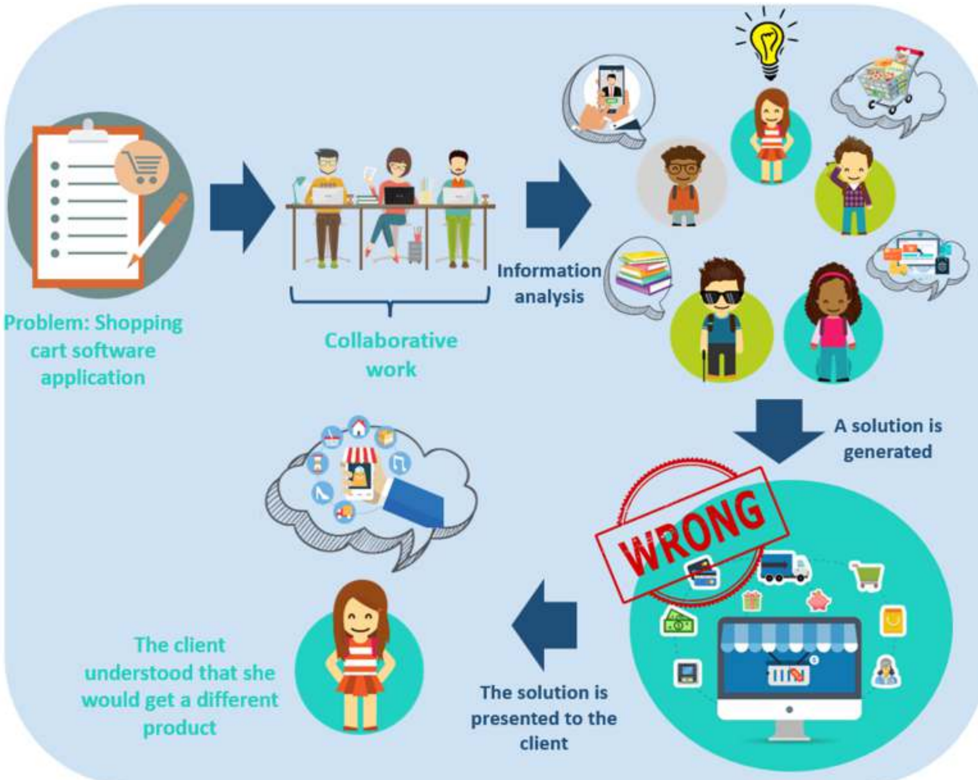


Figure 1.2 Example of the main problem in collaborative work

The following shows in more detail each of the causes of the main problem of collaborative work, which were the basis of this project and guided the development of the proposal implemented.

1.3.1 Difficulty in effective participation of the group members

A general trend in modern work environments is that work is becoming increasingly complex, characterized by the need to perform increasingly complicated problem-solving activities, decision making, rule interpretation, collaborative work processes, etc. Therefore, group members involved in collaborative activities will need to coordinate with their peers the tasks to be performed in order to meet the objectives, including, for example, the assignment and scheduling of responsibilities, the definition of execution times, the assignment of roles, and resources (Schmidt, 1994). When work requires the management of a multitude of intertwined and interdependent activities, the complexity of coordinating these activities increases enormously, and it is here that the field of computer-supported collaborative work research analyzes how collaborative activities and their coordination can be supported by means of computer systems, through best practices and best strategies (Carstensen & Schmidt, 1999) for the group of people to contribute their ideas and knowledge to achieve a common goal (Lai, 2011). Likewise, the importance of teamwork arises from the consideration that the greater the number of participants committed to carrying out an activity, the greater the quantity and quality of the results obtained (Bronstein, 2003).

The collaborative work is the core of the society, carved with difficulties and benefits, one of these difficulties is the lack of effective participation in the development of the different ideas that arise during the development of the collaborative activity with all the other members (Persico, Pozzi, & Sarti, 2009). Therefore, it is necessary to establish social rules to organize and execute it (Bronstein, 2003). In the same way, each person in a team has strengths and weaknesses, communication preferences, and personal goals (Kip & Schaefer, 2014), which when not handled correctly, can fundamentally affect the way of working, generating communication difficulties, where each individual does not provide their necessary and effective contributions to achieve the objectives of the collaborative activity (Hsieh, 2006), in addition, an individual who cannot communicate with his group, will have little motivation to collaborate, and these difficulties will increase if the actions are performed without the necessary coordination, which allows these situations not to happen (Bedwell, et al., 2012). In this sense, groups that present continuous interaction promote mutual verbal understanding through mutual support and required assistance (Londoño, 2008). The interaction will allow true collaborative work to emerge, and this will favor the efforts of the group members to bear fruit, facilitating the success of each member to achieve the common goal (Johnson & Johnson, 2008). It is here where the importance of a quality dialogue (active listening and participation) is fundamental for interaction in order to foster understanding among participants and thus, collaborative work (Vinagre Laranjeira, 2010). This dialogue must go beyond the simple exchange of meanings, since a true dialogue promotes active listening skills (listening attentively to others and providing feedback), generating empathy, that is, putting oneself in the other's place, motivating oneself, understanding and inquiring about what is being communicated, responding with the right words, understanding and making people understand what to do and how to apply the right actions to solve the collaborative activity (Stigliano & Gentile, 2008).

1.3.2 Cognitive aspects are not considered or analyzed

Roschelle and Teasley (1995) define collaboration as "...a coordinated and synchronized activity that is the result of an ongoing attempt to build and maintain a shared understanding of a problem". From this definition, it can be inferred that for collaboration to happen, there must be a SU of the problem being solved, "of what" will be done in the collaborative activity, as this is an important determinant of group performance (Langan-Fox, Anglim, & Wilson, 2004), (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000), and allows participants know where they are going and thus act in a coordinated manner towards the same goal (Mulder & Swaak, 2002). This is why, in order to collaborate effectively and efficiently it is necessary first, to help groups converge on a SU (Christiane Bittner & Leimeister, 2013), so as to have some common knowledge and understanding, which functions as a joint baseline (Smart, et al., 2009). To seek to improve collaborative work is to find the application of techniques and processes that support the creation of SU, which are expected to gain efficiency in the work and produce better group results (Mohammed, Ferzandi, & Hamilton, 2010).

However, current research approaches pay special attention mainly to the processes followed and the tools provided to aid communication and interaction among team members; but the cognitive aspects that are critical in groups and that ensure that the team works effectively and efficiently towards a common goal in such a way that enhances collaborative work are often absent (DeFranco, Neill, & Clariana, 2011). One of these cognitive aspects is SU, which has a number of advantages and benefits when built in a collaborative activity (Martin & Fricker, 2015), but despite this, there are some problems in this regard, among which are: There is a lack of attention and research on the systematic development of the processes that lead to the construction of a SU within heterogeneous groups, in addition to not knowing how to maintain this understanding during the execution of collaborative activity (Christiane Bittner & Leimeister, 2013). Therefore, it is necessary to explore and analyze the optimal degree of heterogeneity in a group that allows building a correct and adequate SU, as well as the optimal degree that a group should have about a given object of understanding, which allows to the members of a group to collaborate effectively but maintaining the benefits of the diversity of each of its members to support in obtaining the expected results (Bittner & Leimeister, 2014).

Another problem is the lack of knowledge about the specific patterns that lead to the construction of SU (Van den Bossche, Gijselaers, Segers, Woltjer, & Kirschner, 2011). It is necessary to investigate, for example, knowledge properties such as the ability to revise and connectedness, as well as social and cultural factors of the participants (Hunt, 2000), without neglecting, the analysis of the relationship to other human factors structures that are involved when working in a group (Smart P. , 2011). Furthermore, as little is known about what leads to SU, practitioners need guidance on how to deliberately and repeatedly evoke processes (Bittner & Leimeister, 2014). If one seeks to create SU in a collaborative activity, it must look at how a single person works and how the group works to solve the activity (Van den Bossche, Gijselaers, Segers, Woltjer, & Kirschner, 2011), as it is not simply getting people together and forming groups, conveying to them the need to solve something, and expecting them to create SU without the necessary support and also collaborate to solve the problem. To do this, the participants must have guided work processes so that interact continuously, collaborate, share their understanding of what is happening, of the activity being developed, generate debates on proposed ideas, listen, make feedback, reach consensus, improving unequal understandings and with this, finally reach a common point, where they coordinate, all participate and agree, obtaining optimal results (Langan-Fox, Anglim, & Wilson, 2004).

Piirainen et al. (2012) identify the construction of a SU as one of the five critical challenges, this challenge can be complicated due to, for example, that the participants have a number of differences in various aspects, for example, in their lived experiences, knowledge, in language, in the words they use or how they express or communicate, which makes it difficult for them to understand each other (Hsieh, 2006) (Smart P. , 2011). In addition, there is the difficulty that in a group all the opinions of the participants are considered, their points of view, and also, that they agree with the problem to be solved in the activity, with the activities to be executed to solve it, with the decisions taken and with the results obtained (Kleinsmann, Bujis, & Valkenburg, 2010), (Garfield & Alan R. , 2012). This demonstrates the need to have elements that allow the construction of the ED and instruments for its measurement in its three categories (construction, co-construction, and constructive conflict) (Bittner & Leimeister, 2014). Future research should aim at a better understanding of this complex phenomenon, its antecedents, and its effects, thus generating more promising opportunities to develop more techniques to leverage its benefits for effective group work (Barron, 2000).

1.3.3 Lack of monitoring of the actions carried out

Collazos et al. (2014) define that: for a collaborative process to be effective, several important aspects must be considered, such as the formation of groups, definition, and assignment of roles and materials, and definition of the collaborative activity, among other aspects. It is also necessary to define a monitoring scheme, where the person in charge knows when and how to intervene in situations of the collaborative activity where the direction is lost or is not doing what is required, which is why monitoring should be done with the objective of improving the process by redirecting the participants. It is important to first understand the collaborative process that occurs when developing an activity considering all these aspects. One way to understand this process is to model, monitor, and evaluate it (Scagnoli N. , 2005). According to Johnson and Johnson (1990) the availability of mechanisms for monitoring participants within a group activity can be very useful to identify people with low participation or groups with an unbalanced distribution of tasks or tasks that are being executed in the wrong way. This identification process, in turn, will allow the person in charge to intervene when he/she considers it appropriate, guiding the group members with the steps to follow so that the actions are carried out properly, promoting discussion among the members and reflection on the activities, and thus carrying out preventive or corrective actions in time so that participation is adequate and the results are obtained according to expectations (O'Donnell & O'Kelly, 1994). Therefore, one way to evaluate group effectiveness is to monitor, observe and evaluate the interactions between group members, gaining an understanding of the quality of the respective groups' interactions and their progress in developing collaborative activity (Dillenbourg , Baker, Blaye , & O'Malley , 1996), (Webb & Palincsar, 1996).

In the same way, it is necessary to monitor the executed process (Hermans, Haasnoot, Maat, & Kwakkel, 2017), in order to ensure that each of the defined activities, tasks, steps, and guidelines are followed correctly, since not performing its monitoring, it is not possible to appreciate the progress of the process execution, it is not possible to ensure that it is on track to achieve the expected results, it is not possible to observe and understand gaps, difficulties or even new opportunities, and with greater concern, it is not possible to apply corrective measures to optimize the expected results, at the right time (Lauriac, 2016). Monitoring helps to decide on the adjustments that are necessary to achieve the different objectives (Caballé, Daradoumis, Xhafa, & Juan, 2011).

Therefore, and considering the problem presented above in collaborative work and some of its causes, the research question in this project is: ***How to build, monitor, and assist shared understanding to improve computer-supported collaborative work in problem-solving activities?***

1.4 Objectives

For the development of this project, the following objectives were defined to guide the research:

1.4.1 General objective

Define a process[1] to improve computer-supported collaborative work in problem-solving activities through shared understanding.

1.4.2 Specific objectives

- Characterize, according to the literature, the elements of the process such as metrics, indicators, monitoring, and assistance mechanisms.
- Build the process by defining, adapting, and refining the elements that will integrate it.

[1] The process is a logical sequence of organized steps that focuses on achieving some specific result (Humphrey W. , 1989)

- Validate the process with experts to determine the integrity of the elements that integrate it.
- Evaluate the improvement in computer-supported collaborative work through the application of the defined process.

1.5 Hypothesis

To evaluate the objectives described above, the following hypothesis is defined:

Alternative hypothesis: A process for the design, execution and validation of collaborative activities based on elements that allow the construction, monitoring, and assistance of shared understanding, improves computer-supported collaborative work.

Null hypothesis: A process for the design, execution, and validation of collaborative activities based on elements that allow the construction, monitoring, and assistance of shared understanding does not improve computer-supported collaborative work.

Figure 1.3 shows the general relationships between the motivation, the causes of the problem, the objectives, and hypotheses derived from this project.

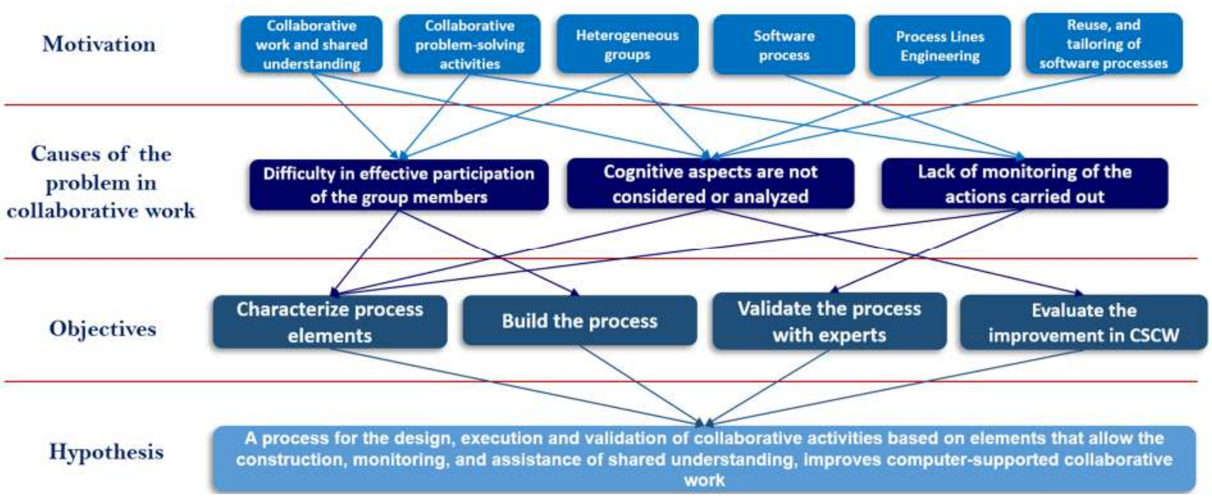


Figure 1.3 Relationships between the motivation, the causes of the problem, objectives, and the hypotheses

As shown in the previous figure, the aspects that motivated this project from the research in collaborative engineering are related to the main causes that generate the problem identified in the collaborative work, which refers to the difficulty of achieving collaboration, and its relationship is framed in that from the motivational aspects the causes that can generate the established problem were identified. In addition, from the analysis of those main elements of software engineering, which would contribute to the construction of the solution, they were also related to the causes present in the problem, and in this way, with the support of software engineering, to structure an adequate solution to obtain a contribution in the identified problem. In the same way, each cause is supported by at least one objective that guided the development of each of the activities carried out in the project, to validate the fulfillment of the hypothesis. Considering all the above, the thesis proposal was to define a process (at two levels: the conceptual level that defines the "how" or the procedure through methods, activities, practices, guidelines, strategies, rules, steps, roles, inputs, results, and a technological level that provides technological support to achieve it) to improve computer-supported collaborative work through the construction, monitoring, and assistance of shared understanding in problem-solving activities. Through this monitoring and accompaniment, mechanisms, strategies, actions, and elements were obtained to maintain the achievement of shared understanding during the design, execution, and validation of the collaborative activity, in such a way that the use of the process improves the collaborative work, which allows the team to work collaboratively in an effective and efficient way towards the solution of a problem and obtaining the expected results.

1.6 Research approach

To achieve the objectives of the project, the scientific method described by Bunge (2002) was selected as the research framework, which was executed in an iterative and incremental manner. In this sense, also this framework was adapted, and the three cycles defined by the multi-cycle action research methodology with bifurcation (Pino, Piattini, & Horta Travassos, 2013) were used. The first cycle refers to the Conceptual Cycle, where the research topic is identified, the analysis of the relevant literature is performed, a plan and design of the research project is made, and as a milestone, the problem statement is obtained. The second cycle refers to the Methodological Cycle, where the steps for the definition of the process are executed and what was planned in the previous cycle is implemented; it is here where the research disciplines are executed, the main activities proposed by Bunge (2002), and the defined and validated process is obtained as a milestone. Finally, the third cycle refers to the Evaluation Cycle, where the research is supervised, and the validated hypothesis is obtained as a milestone.

In addition, specific software engineering research methods and techniques were combined for some of the activities determined.

- For the literature search and review, the guidelines, and procedures for conducting systematic literature reviews defined by Kitchenham (2007) were followed.

To design and propose the process:

- The collaborative engineering approach to design collaborative elements defined by (Kolfschote & de Vreede, 2007) was used.
- The situational method engineering approach defined by (Harmsen, Brinkkemper, & Oei, 1994) was used.

For process validation:

- Process engineering guidelines defined in (Hurtado Alegría, Bastarrica, & Bergel, 2011) (Camacho, Hurtado-Alegria, & Ruiz-Melenje, 2016) were used to validate the process elements.
- The case study research method proposed by Yin (Yin, 1994) was used with the guidelines proposed by (Runeson & Höst, 2009) were used
- Guidelines for conducting and reporting experiments in software engineering defined by (Claes, et al., 2012) were used.

Figure 1.4 shows the three cycles defined by the methodology and their corresponding milestones. In addition, each cycle shows the research methods and techniques used to accomplish the necessary, considering that in the Methodological Cycle 5 iterations were executed, which will be detailed below.

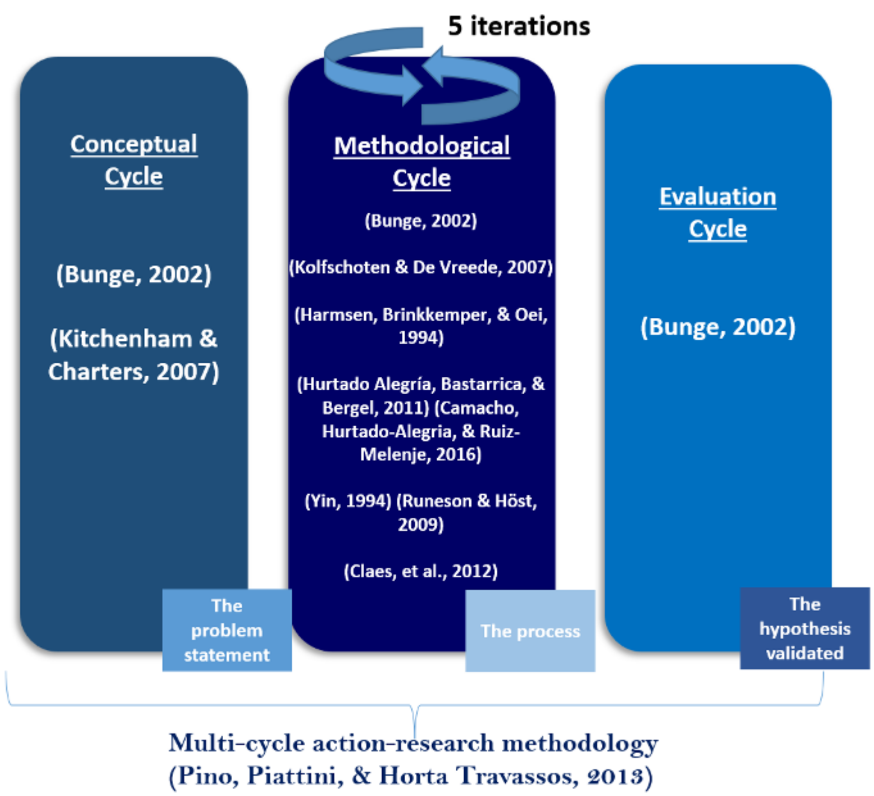


Figure 1.4 Cycles, research methods and techniques, milestones, and iterations

The Bunge activities (2002) that were executed in the different cycles are the following (It is important to clarify that as this research framework was executed as iterative and incremental, in each of the cycles these activities were executed at different levels of effort and as required by each cycle):

1. *Activity: Definition of the research problem*

- Fact-finding: a review of facts, preliminary classification, and selection of the most relevant facts and systematic literature review on collaborative work and shared understanding.
- Problem discovery: finding a gap or missing elements in the literature on computer-supported collaborative work process and shared understanding. Study theoretical references such as processes, methods, frameworks, techniques, and referenced experiences.
- Problem formulation: establish the problem by focusing on a research question according to the available knowledge.

Products obtained: State of the art, problem statement, and research question.

2. *Activity: Construction of the theoretical model*

- Selection of relevant factors: the definition of the different approaches to collaborative work and shared understanding, to achieve a structured characterization of the elements, concepts, strategies, etc. for the design, execution, and validation of the collaborative activity.
- Establish central hypotheses and auxiliary assumptions: it includes proposing a set of assumptions related to the connections between relevant variables.
- Construction of the proposal: Identify the possible elements of the proposal according to the literature and the results of exploratory studies, thereby constructing the process in its different versions.
- Define a proof of concept: use the proposed mechanisms by performing a proof of concept to validate their initial behavior through an exploratory study and an experiment

Products obtained: hypothesis, proposed process, feedback of the process components, design, results, and analysis of: exploratory study and experiment.

3. *Activity: Deduction of specific consequences*

- Search for thematic support: Deduction of consequences that may have been validated in similar contexts using the results of the systematic literature review.
- Search for empirical support: elaboration of predictions based on a theoretical model and empirical data extracted from exploratory case studies and concrete experiences.

Products obtained: Expected results of the process.

4. *Activity: Hypothesis testing:*

In this activity, the developed proposal was evaluated through controlled experiments, expert review, and a case study.

- Validation design: the validation research question is posed, indicators and metrics are defined, and data collection instruments are created, this activity is performed using the case study method proposed by (Runeson & Höst, 2009).
- Validation planning: validation planning according to the hypotheses, research questions, and available groups or organizations that make up the population participating in the validation.
- Execution of the validation: performing the operations and collecting data.
- Validation analysis and report: the interpretation of the data collected is analyzed from the point of view of the theoretical model and the validation report is documented.

Products obtained: Experiment results and analysis, expert review, and case study, discussion, preliminary conclusions, feedback.

5. *Activity: Introduction of conclusions to the theory*

- Comparison of the results obtained with the predictions.
- Relevant adjustments to the process: analysis of results and necessary adjustments to the process.
- Suggestions for future work: search for gaps or errors in the theory and/or empirical procedures that were performed to suggest future work.

Products obtained: Analysis of the results obtained by applying the process, adjustments to the process, and future work.

6. *Activity: Documentation*

- Writing of scientific papers
- Writing of the thesis document

Products obtained: Papers, thesis document

The Methodological Cycle allowed the construction of the process, which was carried out based on previous processes (as will be shown in Chapter 3), literature analysis, and as a result of updates or improvements made according to the results obtained in each validation, in that sense, 5 iterations were executed, which are described below:

- *First iteration*: Initially, the existing processes and elements for the design, execution, and validation of a collaborative activity from the educational context were analyzed, which is the largest area of research on collaboration, and where several papers were written (Agredo-Delgado, Collazos, & Paderewski, 2016) (Agredo-Delgado, Collazos, &

Paderewski, 2016) (Agredo-Delgado, Collazos, & Paderewski, 2016) (Agredo-Delgado, Collazos, & Paderewski, 2016) (Agredo-Delgado, Collazos, Fardoun, & Safa, 2017) (Agredo-Delgado, Ruiz, Collazos, Fardoun, & Noaman, 2017) (Agredo-Delgado, Ruiz, Collazos, & Fardoun, 2019) (Agredo-Delgado, Ruiz, Collazos , & Fardoun, 2019) (Agredo-Delgado, Ruiz, Collazos, Moreira, & Fardoun, 2019). Subsequently, with what was obtained in the literature review and the identified opportunities for improvement, these elements were analyzed in the computer-supported collaborative work (Agredo-Delgado & Collazos, 2018) (Agredo-Delgado, Ruiz, Collazos, Alghazzawi, & Fardoun, 2018), in addition to analyzing the elements that allow the construction of shared understanding. Considering these analyses, the first version of the process was defined, characterized by: being a process with only 2 phases, Pre-Process phase, where the collaborative activity is designed and Process phase where the activity is executed and the shared understanding is built (Agredo-Delgado, Ruiz, Mon, Collazos, & Fardoun, 2020). These two phases were validated through an experiment with a group that used the process and a control group that did not use it, validating the feasibility and usefulness of this first version (Agredo-Delgado, et al., 2020) (Agredo-Delgado, et al., 2021). In addition, an exploratory study was conducted to validate whether this version of the process promotes and improves the shared understanding (Agredo-Delgado, Ruiz, Collazos, & Moreira, 2019).

- *Second iteration*: Considering the results obtained in the previous validations of iteration 1, version 2 of the process was defined. This new version was validated by experts in software and process engineering, who validated the syntax and semantics of the process, in such a way that some errors were identified in the process specification made in SPEM 2.0 (OMG, 2007) were identified.
- *Third iteration*: Correcting the errors found by the experts, a third version of the process was created, which sought to reduce the cognitive load in its use, also including monitoring elements to maintain shared understanding throughout the activity. This version was called THUNDERS (CollaboraTive work through shared UNDErstanding in pRoblems-solving activities). This version was applied in a requirement engineering context, where each of the tasks of this engineering was defined following THUNDERS. The collaborative activity in this validation consisted of defining the requirements for the development of an information management and data processing software system for ASPROLGAN (Asociación de Productores Lácteos y Agro ganaderos del Municipio de Popayán), validating the completeness, usefulness, and ease of use of THUNDERS (Agredo-Delgado, Ruiz, Garzón, España, & Collazos, 2021).
- *Fourth iteration*: Considering the results of the THUNDERS validations, version 4 was generated. This new version was subjected to validation by experts in collaboration issues, in order to select the tasks that are or are not mandatory in the execution of the

process, with the objective of making it lighter and simpler, and in this way, generating new processes that can be adapted to specific contexts, being as extensive or light as required, depending on the characteristics of such contexts. In addition to this, a validation of the process was also performed with AVISPA-Method (Camacho, Hurtado-Alegria, & Ruiz-Melenje, 2016) to make a visual analysis of the process model (Agredo-Delgado, Ruiz, Collazos, & Mon, 2020).

- *Fifth iteration*: With the experts' evaluations, THUNDERS was corrected and updated, thus generating version 5, which was validated in a case study to determine whether its application in a problem-solving activity improves collaborative work, with a group that used THUNDERS and a control group that did not use it. This in order to analyze the differences in both results obtained and determine the improvement in collaborative work with the use of the process.

1.7 Organization of the document

The organization of this thesis document is divided into six chapters which are briefly described below:

Chapter 1. This chapter refers to the contextualization and introduction of the project, which has been divided into its motivation, the problem statement, the project objectives, the solution hypothesis, the research approach, and finally the organization of the document.

Chapter 2. It includes the state of the art, that is., the theoretical references necessary to understand the information presented in the document and that was the basis for the realization of this project, it also includes related works on collaborative work, shared understanding, heterogeneous groups, problem-solving activities, and collaborative processes. In addition, the planning, execution, and analysis of the results obtained from the systematic literature review are presented in order to determine the research conducted so far on shared understanding, its measurement, and specification.

Chapter 3. The detail of the Situational Method Engineering (SME) with each of its activities is shown, which was used to build the process to improve computer-supported collaborative work through the building, monitoring, and assisting shared understanding in problem-solving activities, resulting in the THUNDERS process.

Chapter 4: The philosophy of the THUNDERS process is presented with its specification for collaborative work, in addition to showing the elements that compose it in each of its phases with each of its activities, tasks, steps, roles, work products (inputs, outputs, templates, guidelines), which allow the process to be executed in a specified context.

Chapter 5. The planning, design, execution, results, and analysis of the validation of each of the five versions of the process are presented. Showing the validation of the first version with an experiment and an exploratory study, the second version with an expert review on the specification of the process, the third version with an experiment in the requirement context, the fourth version with an expert review on collaborative aspects, and finally, the fifth version was validated with a case study to determine the improvement of collaborative work with the use of THUNDERS.

Finally, **Chapter 6**. It presents the conclusions and their articulation with the set of objectives, the fulfillment of the hypothesis, the main contributions and limitations of this thesis, and some future work. It also shows the research results obtained during the development of this project.

Chapter 2

BACKGROUND AND STATE OF ART

2.1 Overview

This chapter presents a contextualization of some important concepts necessary to support this project, it also presents related works that served as support and basis to define the proposal, and finally, it presents the planning and execution of a systematic literature review on the definition, measurement, and construction of shared understanding. The chapter is divided into three sections (See Figure 2.1), the first section presents the most relevant concepts on collaborative engineering: specifically on collaborative work, heterogeneous groups, problem-solving activities, and shared understanding, and presents the most relevant concepts of software engineering: specifically on processes, software process modeling, software process line engineering, and software process tailoring. The second section presents related work associated with shared understanding, problem-solving activities, monitoring, and assistance of the collaborative process. Finally, the third section presents a literature review in order to determine the research conducted, up to the time the review was executed, on the shared understanding that allowed guiding the construction of the proposed approach. The sections of this chapter are summarized in the following image (See Figure 2.1).

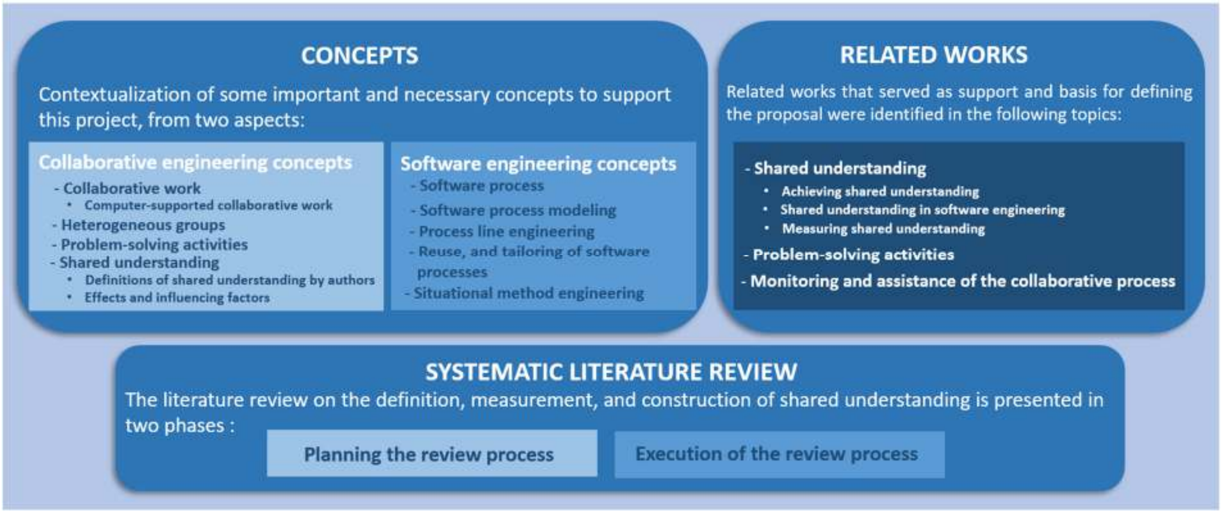


Figure 2.1 Sections presented in this chapter

2.2 Collaborative engineering concepts

Collaborative Engineering (CE) is an approach to the design and implementation of collaborative processes that includes collaborative work practices in recurring activities where teamwork is a relevant success factor (Briggs , Kolfschoten, de Vreede, & Douglas , 2006) (de Vreede, Briggs, & Massey, 2009). These collaborative processes can be executed by practitioners for high-value tasks, where a collaboration engineer designs collaborative processes and transfers them to practitioners in an organization (Kolfschote & de Vreede, 2007). Thus, in this sense, collaboration is the process of multiple people working together interdependently to achieve a goal greater than any individual can achieve alone (Sandler, 1992). The goal of this human-centered discipline is to enable people to work more effectively with all stakeholders to achieve rational agreements and perform collaborative actions across diverse cultural, disciplinary, geographic, and temporal boundaries (Lu, 2004).

Considering this, within collaborative engineering, other important concepts will be used during the development of this project, which will be defined below:

2.2.1 Collaborative work

It is the one in which a group of people contribute their ideas and knowledge to achieve a common goal, seeking the production of knowledge, unlike teamwork where the optimization of results is sought (Leeann, 2015). The so-called collaborative work is defined when team members convene a meeting to solve a problem, which in most cases is technical (Robillard & Robillard, 2000). In this sense, collaboration involves direct interaction between individuals to produce a product and involves negotiations, discussions, and reaching a consensus on the perspectives or ideas of others to obtain the expected results (Kozar, 2010).

2.2.1.1 Computer-supported collaborative work

Computer-supported collaborative work (CSCW) is a multidisciplinary research field that focuses on tools and techniques to help multiple people work on related tasks, providing support to individuals and organizations for group collaboration and task orientation in distributed or networked environments (Grudin, 1994).

CSCW has been interpreted and understood in several different ways by different authors, some researchers use the term to express the idea of collaboration among a group of people using computers (Bannon, et al., 1988) (Kling, 1991). It is also known as "software for a group of people" or "groupware" (Hughes, Randall, & Shapiro, 1991) Suchman (1989) also said that it is "the design of computer-based technologies with an explicit concern for the socially organized practices of their intended users". For others, it is the study of how people use hardware and software technologies to work together in shared time and space (Rama & Bishop , 2006). According to Bannon et al. (1988), it is "an effort to understand the nature and characteristics of collaborative work with the goal of designing appropriate computer technologies." This definition combines an understanding of how people work in groups and how computers and network technologies can be designed to support activities. On the other hand, CSCW systems are collaborative environments that support dispersed workgroups to improve quality and productivity (Bowers & Benford, 1990). This definition divides the concept into two components, first, understanding how people work together as a team to accomplish a common task, and second, developing efficient computer software and hardware that facilitates interaction among a group of people. Combining the two points of view (work-centered and technology-centered), researchers are trying to better understand the process of teamwork and then develop collaborative computing systems to make it easier for group members to work together (Alam, Ullah, Rabbi, Khalid, & Din, 2013).

2.2.2 Heterogeneous groups

Heterogeneous grouping is a type of organization of people where there is a relatively even distribution of participants with different intellectual abilities, different emotional needs, varying ages, educational levels, interests, special needs (Razmerita & Brun, 2011). It is necessary to bring mixed ability groups together systematically to ensure a truly heterogeneous composition (Barron, 2003). These heterogeneous compositions are ideal for helping people with difficulties, as they allow everyone to benefit from each other, supporting each other and can be a complement, without making one member take on too much of the workload or leadership (Graf & Bekele, 2006).

Research suggests that these compositions generate positive effects on performance, self-esteem, intergroup relations, and greater acceptance of group members (Slavin, 1991). The idea of collaborative heterogeneous group work is to design group work that requires the multiple skills of group members to solve, manage and complete a complex task, which has the uncertainty of a challenge (Cohen & Lotan, 2014) and needs the contributions of all group members (Lotan, Swanson, & LeTendre, 1992). Some studies emphasize that heterogeneous groups can be more creative and innovative (Paulus & Nijstad, 2003). The first heterogeneity criteria were related to the level of knowledge and skills (Slavin, 1987), (Webb, 1989), currently others have been incorporated such as diversity of experiences, beliefs, opinions (Siemens, 2014), ideas, personality, gender, learning styles, among others (Slavin, 1990).

2.2.3 Problem-solving activities

Problem-solving is the act of defining a problem, determining the cause of the problem, identifying, prioritizing, and selecting alternatives for a solution, and implementing it (Beecroft, Duffy, & Moran, 2003). Furthermore, collaborative problem solving (CPS) has been named by researchers as one of the core 21st-century skills (Care, Scoular, & Griffin, 2016), becoming an important competency in the educational and professional fields (Rosen & Foltz, 2014).

CPS is defined as (O'Neil, Chuang, & Chung, 2003) "problem-solving activities involving collaboration among a group". From this definition, it can be seen as composed of two parts, "collaboration" and "problem-solving". Mayer and Wittrock (1996) postulated problem-solving as a "cognitive processing aimed at achieving a goal when no method of solution is obvious to the problem solver.", it is also defined as "... the ability of an individual to engage effectively in a process by which two or more agents attempt to solve a problem by sharing the understanding and effort required to arrive at a solution and by pooling their knowledge, skills, and efforts to arrive at that solution" (2013).

2.2.4 Shared understanding

In the 1950s, a view of cognition and understanding as processes occurring in someone's head or mind was established (Norman, 1991), with no emphasis on group activities, normal everyday situations, or natural observations. However, in the early 20th century, when the now well-known activity theory began (Rogoff & Wertsch, 1984) Vygotsky postulated that mental functioning occurs first between people in social interaction and then within the person's mind (Mendoza García, 2021). Today, in many social sciences and computer science disciplines, practitioners examine the world from a situated activity perspective (Hunt, 2000).

On the other hand, shared understanding should not be confused with shared knowledge (Wittgenstein, 1967), the origin of the word *knowledge* goes back to the Greek gnosis or Sanskrit gnana, it refers to direct and immediate contact with reality, while the word *understanding* refers to being close to reality (Soares Correa da Silva & Agusti-Cullell, 2008). Shared knowledge refers to the mutual recognition of integration with reality, moreover, it is considered with an unnecessary flow of information, since it only occurs when a group of agents is already integrated with reality and, through reality, with each other, for its part, shared understanding, refers to agents constructing equivalent artificial information systems, as a result of individual perceptions and the flow of information (Hinds & Weisband, 2003). therefore, is a result or consequence of information flow, and cannot be built without it (Soares Correa da Silva & Agusti-Cullell, 2008).

2.2.4.1 Definitions of shared understanding by authors

Many authors over time have given different definitions to SU from different aspects, for example, considering knowledge, the authors define it as "Mutual knowledge, mutual beliefs, and mutual assumptions" (Mulder & Swaak, 2002). According to Kleinsmann et al. (2010) it is when the group should be able to integrate their knowledge bases in a sensible way. For Mulder et al. (2002) it is "The overlap of understanding and concepts among group members." Similarly, Bittner and Leimesister (2014) said that it "refers to the degree to which team members agree on the steps in the work process, the meaning of those steps, the order and relationship of activities with respect to the specific work processes to be documented".

On the other hand, considering SU as a skill, the authors define it as "A skill, which is common to multiple agents. Similar performances of multiple agents may be sufficient to merit conclusions about shared understanding" (Smart, 2011). Furthermore, Christiane Bittner and Leimeister (2013) define it as "The ability to coordinate behaviors towards common goals or objectives ("meaning-in-use" or action perspective) of multiple agents within a group (group level) based on mutual knowledge, beliefs and assumptions (content and structure) about the task, the group, the process or the tools and technologies used (object scope/perspective) that may change throughout the group work process due to various influencing factors and impacts the processes and outcomes of group work”.

Considering the interaction between group members, the authors define it as "the moment when members create a new joint perspective that emerges from their collective contributions" (Wanstreet & Stein, 2011). Similarly, for (Soares Correa da Silva & Agusti-Cullell, 2008) “it is what happens when equivalent artificial information systems are constructed, and the corresponding mappings between these are also constructed by each agent engaged in a dialogue, enabling a group of agents to act in a coordinated manner so that they can collaborate with each other to achieve their individual objectives. SU is a prerequisite for collaborative work among many agents when two agents engage in a dialogue".

2.2.4.2 Effects and influencing factors

There are many benefits to building the SU in collaborative groups, which have been investigated and proven by several authors, among these benefits are: it allows predicting the performance of the group, obtaining better quality and quantity of products, in addition, it is more likely that the team will be successful and minimize time losses due to reprocessing (Langan-Fox, Anglim, & Wilson, 2004), (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). Similarly, it allows the satisfaction of group members (Langan-Fox, Anglim, & Wilson, 2004), achieving the coordination of tasks, resources and people. It also enables successful and efficient communication in globally distributed projects, considering that cultural diversity poses challenges, since having different cultures, group members have disparate communication and problem-solving processes (Hsieh, 2006). In other words, team members coordinate their actions by having an SU of work (Ilgen, Hollenbeck, Johnson, & Jundt, 2005). This is why, when achieved, it reduces iterative work cycles among group members and rework (Kleinsmann, Bujis, & Valkenburg, 2010), it can also promote a more efficient and effective collaborative work (Kleinsmann & Valkenburg, 2008), improves team morale (Darch, Carusi, & Jirotka, 2009); generating less conflict and distrust among team members. On the other hand, the absence of SU can generate conflict and distrust, generating a greater need for negotiation, consultation, and monitoring, providing more opportunities for conflict to arise (Hinds & Weisband, 2003).

On the other hand, some factors that influence the SU are: Individual differences and environmental factors. Factors related to the individual and the group include, for example, personality and individual skills, familiarity with the team, authority, and diversity (Kleinsmann & Valkenburg, 2008), (Pascual, 1999). Environmental factors such as physical proximity, incentives, communication support or organizational culture have also been discussed (Langan-Fox, Anglim, & Wilson, 2004), (Hsieh, 2006), (Kleinsmann & Valkenburg, 2008), (Deshpande, de Vries, & van Leeuwen, 2005). Factors related to the collaborative process (Kleinsmann & Valkenburg, 2008) such as reasoning and communication, visualized beliefs and evidence, separation of individual and shared activity spaces and training (Darch, Carusi, & Jirotka, 2009), (Mohammed & Dumville, 2001), (Deshpande, de Vries, & van Leeuwen, 2005), (Du, Jing , & Liu, 2010). Factors such as nationality, background, language, attitudes, and values contribute to shared understanding (or misunderstanding) (Smart, 2011).

2.3 Software engineering concepts

Software engineering (SE) is an engineering discipline that deals with all aspects of software production, using well-defined scientific principles, methods, and procedures, from the early stages of system specification to its maintenance once it has entered into use (Sommerville, 2011). In this definition, there are two key phrases (Pressman, 2010):

- *Engineering discipline*: engineers make things work, applying theories, methods, and tools when appropriate.
- *All aspects of software production*: SE is not only concerned with the technical processes of software development. It also includes activities such as software project management and the development of tools, methods, and theories to support software production.

Considering this, in this project SE is taken as the guide that will give the guidelines, principles, methods, and scientific procedures necessary for the definition, construction and validation of the proposed process, that is why it is necessary to define some concepts that will be used in this project.

2.3.1 Software process

The systematic approach used in software engineering is called software process (Sommerville, 2011), for this reason, this project is based on the concept of software process to determine the outcome of this research. According to this, the definition of software process refers to the set of tools, methods and practices to produce a software artifact (Humphrey W. S., 1989) (Hossein & Natsu, 1997) (Ginsberg & Quinn, 1995). It is also defined as a set of activities, methods, practices and transformations that people use to develop and maintain software, as well as its associated products (e.g., plans, specifications, designs and tests), on the other hand, it is a set of activities necessary to transform user requirements into a software system (Xu, 2005). Similarly, for Acuña et al. (2001), it is a partially ordered set of activities performed to manage, develop, and maintain software systems. Considering these definitions and seeing the main problem of collaborative work and how software engineering can support and improve this problem, it was taken for the Process, the definition that it is an ordered sequence of steps with some kind of logic that focuses on achieving some specific result (Humphrey W. , 1989), the result for this project is the improvement of collaborative work through the construction, monitoring and assistance of shared understanding.

In this sense, SPEM 2 (OMG, 2007) is a metamodeling standard that serves to represent software engineering processes, where a Software Process (SP) is "A coherent set of policies, organizational structures, technologies, procedures and artifacts that are necessary to conceive, develop, install and maintain a software product". A Metamodel describes a set of generic concepts and their interrelationships, which serve as a basis for the definition of Models of a certain Domain. Therefore, a metamodel is a model of models. By using a metamodel, models of the corresponding domain can be represented. Applying these ideas to the domain of software processes, PS models are built by instantiating the concepts of the generic PS metamodel, i.e., SPEM. This instantiation is determined by the characteristics of the model to be built. In the design of a PS model, the relationships between the different concepts defined in SPEM must be respected.

Specifically, in SPEM 2, two concepts are distinguished when implementing a process (See Figure 2.2):

- First, the Method Content is populated with Content Elements, i.e., the primary elements or basic constructors, and they are derived from the primitive work pattern: someone (role) does something (task) to obtain something (work product) based on or aided by something (guidance). Accordingly, the content element types are: Task, Role, Work Product, Guidance, and Category.
- These elements are then combined and reused to obtain Processes.

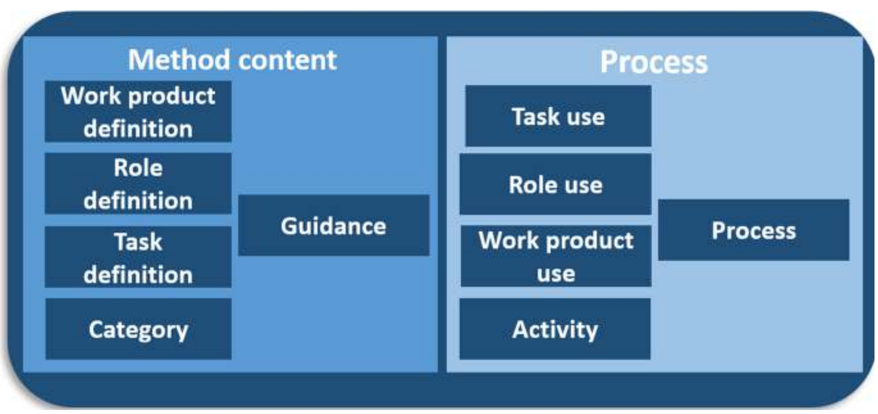


Figure 2.2 Main aspects to model with SPEM

2.3.2 Software process modeling

Software process modeling describes the construction of software development process models (Sommerville, 1996). A software process model is an abstract representation of the architecture, design, or definition of the software process (Feiler & Humphrey, 1993). For Acuña et al. (2001) software process modeling refers to the definition of the processes as models, plus any optional automated support available to model and execute the models during the software process.

2.3.3 Process line engineering

Process Line Engineering (SPrLE) defines a process and the necessary elements to be followed in the planning and materialization of a Software Process Line (SPrL), that is, it is the framework for its construction. SPrLE defines two main processes for the construction of an SPrL: domain engineering (construction) and application engineering (adaptation and implementation). Domain engineering refers to the definition of structural elements of the SPrL, and application engineering is responsible for deriving process instances that satisfy specific situations (development of products and projects with similar characteristics) (Hurtado & Bastarrica, 2012) (Armbrust, et al., 2008).

For Armbrust et al. (2009) an SPrL is "*a set of software processes with a managed set of characteristics that meet the specific needs of a particular organization and are developed from a common set of core processes in a prescribed manner*". Furthermore, for Ternité (2009) it is "*a set of processes that capture similarities and controlled variabilities*". Each of these processes develops from a common set of core assets (characteristics) in a prescribed manner.

2.3.4 Reuse, and tailoring of software processes

One strategy to accelerate process improvement is to replicate standard organizational processes within other contexts (Barreto, Murta, & Cavalcanti da Rocha, 2011). A reusable process can be defined as the use of a process description in the creation of another process (Hollenbach & Frakes, 1996). On the other hand, the adaptation of software processes is "the act of adjusting the definition and/or particularizing the terms of a general description to derive a description applicable to an alternative (less general)" (Ginsberg & Quinn, 1995).

A software process defines the activities to be performed, the interdependence between them, their inputs and outputs, the input and output criteria for each, and the roles of the various stakeholders involved in each (Olson, Reizer, & Over, 1994). For this reason, building a software process is a knowledge-intensive and time-consuming activity in which success depends largely on the prior experience of the practitioners (Henninger , 2001). Building processes from scratch each time is risky and involves a great deal of overhead. Therefore, processes are often created by reusing or adapting existing processes and standards (Peng & Ramesh, 2007), where adjustments to standard software processes are necessary to make them suitable for the specific environment (Baskerville & Stage, 2001).

2.3.5 Situational method engineering

Situational method engineering (SME) is the engineering discipline for designing, building, and adapting methods, techniques, and tools for software systems development. A method can be defined as an approach to carrying out a software systems development project, based on a specific way of thinking, consisting of guidelines, rules, and heuristics, systematically structured in terms of development activities, with corresponding development, work products, and developer roles (Henderson-Seller, Ralyté, & Ågerfalk, 2014). Design and construction of methods based on method engineering are performed from method parts as a building unit that can be method fragments, method chunks, or method components (Henderson-Seller, Ralyté, & Ågerfalk, 2014) (Henderson-Seller, Situational Method Engineering: Stateof art of the-Art Review, 2010).

A method consists of one or more method components (Karlsson & Wistrand, 2006), a method component focuses on the (input/output) artifacts, called work products, and the process used to transform the input work products into output work products. All fragments or components of a method are related to one or more objectives. If a fragment is part of a method, it must have at least one reason to be there (Henderson-Seller, Ralyté, & Ågerfalk, 2014). Method engineering focuses on constructing methods by selecting components from existing methods or from a repository called a base method (Karlsson & Wistrand, 2006).

2.4 Related works

The following are the works that are associated or have previously worked on the main themes of this research, in order to show the originality and the main contributions of this project. The related works are associated with the following main themes: shared understanding, collaborative problem-solving, and, finally, monitoring and assisting collaboration.

2.4.1 Shared understanding

2.4.1.1 Achieving shared understanding

Initially, research that has focused on the construction of shared understanding will be shown, among them: Granados in (2000) studied shared understanding within a group, analyzing the conceptual structure from the messages and types of messages that group members exchange while performing the task, defining that shared understanding is achieved with messages, clarifications type statements, as well as questions formulated within the group, which must be encouraged by a coordinator to allow its achievement. Similarly, De Haan (2001) was concerned not only with how groups define the object of the activity (the task model), but also with the so-called "team interaction model" in which divided roles and responsibilities are used to solve a particular task and analyze these interactions to achieve a shared understanding. On the other hand, in (Bittner & Leimeister, 2014), they conceptualized shared understanding, applying collaborative engineering to derive a validated collaborative process module (using the thinkLet "MindMerger") to systematically support heterogeneous workgroups in building shared understanding, which was applied in a scaled action research study, in a German automotive manufacturing company. The evaluation indicated that with the use of MindMerger, team learning behaviors occurred, and shared understanding of tasks increased. Similarly, in (Gomes, Tzortzopoulos, & Kagioglou, 2016) a model of the shared understanding building process was designed, which incorporates three main features: division of labor, coordinated perception, and mediated coupling. Where in a preliminary analysis it is shown that set-based design, has the potential to address parts of this process by engaging participants in situations where they need to build shared understanding. However, there is still a need for further research on how this process occurs and how management strategies could be adopted to improve collaboration through greater shared understanding in the early stages of design. On the other hand, Stein et al. (2007) investigated the process by which shared understanding develops in a chat learning space, using a hands-on research model to assess the development of cognitive presence and how the pattern of conversation in synchronous discussion supports cognitive presence and how these changes over time. Meanwhile, building on questioning theory, the work presented in (Cash, Dekoninck, & Ahmed-Kristensen, 2017) uses a quasi-experimental study to test the impact of questioning support in homogeneous and heterogeneous teams. The results show a significant improvement in a shared understanding for both types of teams (27% improvement for heterogeneous and 16% improvement for homogeneous), as well as substantial differences in how this improvement is perceived. Showing the value of implementing communication support tools, as well as the need to ensure that teams accept the support by making improvements visible. In (Souren, Fang, & Dennis, 2018) examined short-term virtual teams engaged in data model development tasks. They found that group atmosphere has a strong influence on both the development of shared understanding and team conflict. Furthermore, that cultural diversity facilitates the development of shared understanding in virtual teams. In (Aubé, Rousseau, Brunelle, & Marques, 2018) tested a second-stage moderated mediation model, in which the mediating role of team members' proactive behavior on the relationship between perceived shared understanding and team performance is moderated by team adaptability. The study highlights the importance of fostering the perception of being "on the same page" to motivate members to be proactive and improve team performance, this is through the organization of strategic planning workshops, team building sessions, team coordination training, and reflexivity exercises. On the other hand, in the work developed by (Kniel & Comi, 2021) they contributed by exploring designers' perceptions of shared understanding in remote teams. Analyzing the perspective of individual designers working in remote teams, they pursued two objectives: to discover the work elements perceived to require shared understanding and, secondly, to identify perceived enablers and barriers to accumulating shared understanding. It was found that team spirit, shared experience, trustworthiness, and transparency, as well as project management and related micro-practices, are perceived as fundamental to generating shared understanding in remote design teams.

2.4.1.2 Shared understanding in software engineering

On the other hand, those studies that have been carried out in the field of software engineering are shown, which is considered knowledge-intensive, making it particularly dependent and with a need to achieve shared understanding in its various actions performed. This is why knowledge management to enable collaboration within the software team and between the team and its stakeholders have received much attention (Bjørnson & Dingsøyr, 2008). In this regard, an empirical study on how to establish mutual understanding in system design is presented in (Margaret, 1994), where three processes were found to help establish mutual understanding between system analysts and stakeholders: "(1) perspective change, (2) transaction management, and (3) rapport-building". Whitehead (2007) in turn, discusses collaboration in software engineering and states that model-based collaboration is an important means to achieve shared meaning. Couglan and Macredie (2002) discuss the importance of achieving shared understanding to elicit and communicate requirements effectively, arguing that an emergent, collaborative approach is crucial to elicit successful requirements and, eventually, better-shared understanding. Arikoglu (2011) investigates the impact of the use of scenarios and persons on requirements elicitation and design, testing the hypothesis that their use improves shared understanding. Similarly, Werner (2021) describes the unique, complex, and intricate relationship between shared understanding of non-functional requirements (NFR) and continuous software engineering (CSE), describing CSE-related factors that affect shared understanding of NFRs. In particular, there is evidence to suggest that a possible side effect of CSE is a decrease in the shared understanding of NFRs. This project also describes best practices for effectively building, managing, and maintaining shared understanding in CSE. In the project defined in (Varas, 2021) a technique is proposed to help parties generate shared understanding, during the initial project period. The application of this technique, called CORAS (COllaborative RApid Scoping), involves a collaborative activity involving representatives of the client and the developer, who use a support tool (CORAS-Tool) to interactively define the scope of the product. The agreements reached between the parties are made explicit in a visual prototype of the software to be developed, in order to reduce, during the project conception stages, ambiguity or lack of information on the scope of the system to be built. Nakakawa et. al. (2018), explore ways to decrease the lack of shared understanding among stakeholders in collaborative enterprise architecture development by adopting situational method engineering to guide the development of a method to enable stakeholders to acquire a shared understanding of requirements for enterprise architecture. On the other hand, Hsieh (2006) identifies geographical, temporal, organizational, and cultural boundaries as barriers to shared understanding in distributed requirements engineering, introducing a theoretical framework to investigate the impact of culture. McKay (1998) proposes a technique called cognitive mapping to achieve the shared understanding of requirements. Hill et al. (2001) attempt to identify shared understanding by analyzing the similarity of documents produced by team members, based on latent semantic analysis. For their part, in the project defined in (McCarthy, O'Raghallaigh, Fitzgerald, & Adam, 2019) they developed a framework to investigate the interaction of factors that shape shared understanding and shared commitment during agile distributed information systems development project team interactions, it was found that shared interaction shared understanding, and shared commitment in this type of team are determined by the dynamic interaction between macro-level (contextual) and micro-level (localized) factors. As part of the work done in (Ingrid, Swaak, & Kessels, 2002) shows an empirical study exploring group learning and shared understanding in a globally distributed engineering team, as part of a project called International Networked Teams for Engineering Design (INTEnD), for research on the evaluation of geographically dispersed engineering teams. The work conducted in (Humayun & Gang, 2013) aimed to investigate the role of a clear organizational structure with communication responsibilities and a knowledge management practice, in the development of a shared understanding of requirements in Global Software Development, where a controlled experiment was conducted in an academic environment with two geographically distributed groups of students. The understanding patterns of both groups were observed by performing multiple concept mapping exercises, the results revealed that a clear organizational structure with communicative responsibilities helps to improve shared understanding. In (Rosenkranz, Hummel, & Holten, 2016), an empirical study was conducted in a software product development company in which a quantitative survey design is used and complemented with seven semi-structured interviews for the perception of shared understanding construct, furthermore, it is addressed how team distribution influences project success, using a shared understanding approach. On the other hand, Dossick et. al. in (2017) show the first findings of an empirical study that seeks to explore the use of Photo Elicitation techniques in combination with ethnography to assess the amount of shared understanding in multidisciplinary teams working on a building design project. In addition, the construction management, and visualizations that these students created and used to learn and develop integrated skills were studied. The results of two studies are shown in (Jentsch, Beimborn, Jungnickl, & Renner, 2014): an experiment with students and a pilot field study with professionals using a content validity survey instrument to measure shared understanding in companies and IT professionals that aims to monitor the relationships between companies and IT units in their organizations.

2.4.1.3 Measuring shared understanding

Research has also been conducted on how to measure shared understanding, and some work related to these measures is presented below: In (Sieck, Rasmussen, & Smart, 2010) it is suggested that one way to measure shared understanding between agents (whether individuals or groups) is to assess the structural isomorphism of the cultural models developed by the agents in question. If the models are identical, then the level of shared understanding between the agents involved will be at its theoretical maximum. If the models do not resemble each other, the shared understanding will be minimal. Similarly, in Smart (2011) the measurement of shared understanding is studied based on the assessment of shared skills. The types of responses that justify the attribution of understanding to an individual are determined and then a way to measure those responses is developed. To do this, a cultural model is used in which the nodes of this model represent concepts and associated properties, while the links between concepts reflect the community's beliefs about the relationships and dependencies between concepts. According to this cultural model, it is defined whether or not a shared understanding was achieved. In contrast, Berggren and Johansson (2010) discuss the need for an easy-to-use and administer measure that can capture shared understanding in a team of professionals working together to achieve successful performance. They developed a shared priorities measure of shared understanding that was described using two empirical studies. In the first study, students participated in a micro-world experiment in which they attempted to rank pre-determined factors to measure shared understanding. In the second study, officers from the Swedish Armed Forces participated in an exercise in which they rank-ordered self-generated factors. This measure captured different levels of agreement across teams. Mulder et. al. (2002) described a conceptual framework where a distinction is made between the process of reaching a shared understanding and the resulting shared understanding. To assess group learning and shared understanding in the overall design team, they used a variety of data sources, qualitative and quantitative including observations, transcripts, interviews, questionnaires, rating scales, weekly communication diaries, use of the monitoring system, an expert judgment of performance, and added a self-scoring instrument (Mulder, 1999) to measure the perception of a shared understanding (both process and product), on six- and seven-point rating scales (Likert), where group members defined their perception of understanding on aspects of content, procedure and relationship. Meanwhile, the study by (Jentsch, Beimborn, Jungnickl, & Renner, 2014) was the development of a content validity tested survey instrument that measures the degree of shared business/IT understanding in a multifaceted way, adopting an innovative content validation method, comparing survey results with data from a cognitive measurement approach (repertory grid technique). They provided the results of two studies: an experiment with students and a pilot field study with professionals.

Similarly, research has been conducted to measure the achievement of shared understanding through perception, including previous studies that have validated the use of 7-point Likert scale questionnaires (Preston, Karahanna, & Rowe, 2006) (Badke-Schaub, Lauche, & Neumann, 2007). These questions address several different aspects of perceived shared understanding, which are internally consistent and can be grouped together to give an overall assessment. Similarly, other authors have used Likert-scale questionnaires, such as: (Edelson, 2000), (Ensley & Pearce, 2001), (Levesque, Wilson, & Wholey, 2001), (Mohammed & Ringseis, 2001), (Peterson, Mitchell, Thompson, & Renu, 2000). For their part, Bates et al. (2014) developed and validated a perception questionnaire as a tool to assess shared clinical understanding. A questionnaire was validated among physicians of pediatric cardiology patients that determined whether or not - according to the physicians' critical and objective assessment - there was or was not a shared understanding among these physicians about the delivery of patient information. In (Rosenman, et al., 2018) in a study with interprofessional emergency medical teams, emergency medicine residents, nurses, and medical students independently performed, recorded, and coded resuscitation simulations. This study allowed measurement of the team's perception of shared understanding according to the information provided and a measure of the team leader's effectiveness.

Many authors have measured shared understanding through the use of mental models. In this sense, according to Rouse and Morris (1986): “mental models are defined as: "mechanisms by which humans generate descriptions of the purpose and form of the system, explanations of its functioning and its observed states". Mental models enable team members to form accurate explanations and expectations of their environment (Levesque, Wilson, & Wholey, 2001), and in turn allow them to coordinate their actions and adapt their behavior to the demands of the environment (Cannon-Bowers, Salas, & Converse, 1993). Similarly, Mathieu et al. (2000) define shared mental models as the convergence of individuals' mental models. Some projects using these measures are: In (Johnson & O’Connor, 2008) a research method is presented that defines tools to collect shared mental model data, thereby better understanding team learning, and provides organizations and designers with a mechanism to collect and study team effects in learning and performance scenarios. They define an Analysis Constructed Shared Mental Model Methodology (ACSMM), which is a set of techniques in which individual mental models are elicited and sharing is not determined by the individuals who provided their mental models but by an analytical procedure. This method quickly and easily captures mental models with minimal intervention in the activities of a team. The ACSMM methodology can be provided as feedback to facilitate team performance.

Meanwhile, Braunschweig and Seaman (2014) developed and evaluated a technique to measure the degree of shared understanding and identify areas of similarity and difference. Adapted from the Pathfinder technique for assessing Team Mental Models, this was a quantitative analysis of paired comparisons of design concepts as understood by the team. An empirical mixed-methods pilot study of the technique was conducted with 5 teams of students developing a one-semester project. They used questionnaires and interviews to assess the effectiveness of the technique in measuring areas of similarity and difference. They also investigated the association between differences in comprehension and problems during development. On the other hand, Redlich et al (2017) presented an experiment on the impact of shared mental models (SMM) on creative virtual teamwork. They tested whether the use of an online whiteboard influences the SMM constructs in the initial phase of virtual teamwork, transferring the construct on task measurement and team goal in a creative virtual team process. They identified that this research would act as a starting point for improving creative virtual teamwork through the use of SMM. In the study presented in (Cash, Dekoninck, & Ahmed-Kristensen, 2017), participants developed an individual concept map depicting their understanding of the design plan to be carried out before and after a Phase. A list of inspiring concepts was provided to support participants. Sharing was then assessed against five standard measures of similarity between individuals' concept maps. Before and after scores were compared at the team level to assess change in shared understanding. In addition, a technique for mental models that was used was relationship ratings, which have also been used in (Marks, Burke, Sabella, & Zaccaro, 2002), (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000), (Langan-Fox, Wirth, Code, Langfield-Smith, & Wirth, 2001), (Stout, Cannon-Bowers, Salas, & Milanovich, 1999). In this technique, individual team members are asked to judge the relationship of the concepts provided by the researcher. This information is then used by most authors (except for (Langan-Fox, Wirth, Code, Langfield-Smith, & Wirth, 2001)) as input for analysis, using programs such as Pathfinder and UCINET. A second technique used is concept mapping (Marks, Burke, Sabella, & Zaccaro, 2002), in which participants are asked to choose from a variety of concepts and place them in a pre-established hierarchical structure. A third technique, used in one of the studies (Carley, 1997), is to use idiosyncratic information from team members. In this study, participants answered essay questions. The resulting texts are assumed to contain a part of the author's mental model at the time the text was created (Kaufer & Carley , 1993).

Throughout history research on shared understanding has evolved and different authors have given various names to this concept, including different elements or considering different contexts, some of these names that have been most researched are: common ground, socially shared cognition, distributed cognition, and group cognition (Hunt, 2000). Considering that all these terms refer in some way to structures of collective meaning that emerge and coordinate the activities of a group (Akkerman, et al., 2007) (Annex 1 shows the definitions that have been given to these concepts and some related work that has been done for each of them).

2.4.2 Problem-solving activities

The following are those investigations that have been conducted considering problem-solving activities: For his part, Quashigah (2017) in his research examines target group occurrences and individual contributions in collaborative problem solving (CPS) activities, where use was made of video data asking a group to work collaboratively on various didactic tasks in mathematics and environmental science courses. According to the results of the analysis, 6 CPS activities were discovered, audience awareness (perspective taking), coordination, adaptive responsiveness (perspective taking), problem reanalysis, task exploration, and problem analysis. Similarly, Roschelle and Teasley (1995) in their research focused on the processes involved in collaboration using a microanalysis of a dyad's work with a computer-based environment and by collaborative problem solving involving a computer simulation of concepts in physics. They further proposed that the fundamental activity in collaborative problem solving occurs through engagement with a set of emergent and socially negotiated knowledge elements that constitute a joint problem space. On the other hand, Stewart et al. (2019) investigated the automated detection of three critical SCP processes: shared knowledge construction, negotiation/coordination, and team function maintenance, derived from a validated SCP framework. The data consisted of 32 triads tasked with collaboratively solving a challenging visual computer programming task using commercial videoconferencing software. They used automatic speech recognition to generate utterance transcripts, which the trained humans coded for evidence of the above three CPS processes using a set of behavioral indicators to provide automatic real-time or offline feedback.

Considering problem-solving in learning, the following research was analyzed: Barron (2000) investigated in two groups the interactive processes among peers and the relationship of these processes to problem-solving outcomes. The analyses identified 3 main contrasting dimensions of group interaction: the reciprocity of exchanges, the achievement of joint attentional engagement, and the alignment of group members' goals for the problem-solving process. One objective of the research was to describe the types of interactions that contribute to or inhibit coordination. On the other hand, the project presented in (Häkkinen, et al., 2017) presents their pedagogical framework for 21st-century learning practices in teacher education. They elaborated the processes and strategies for collaborative problem-solving skills and strategic learning skills, this with the aim of outlining pedagogical designs for learning practices in which the core elements are strategic learning skills, collaborative problem-solving skills, and ICT skills. Graesser et al. (2018) developed a CPS proficiency assessment of student skills and knowledge. The assessment framework defined CPS skills by cross-referencing three core CPS competencies with four problem-solving processes to form a matrix of 12 specific skills. The three SCP competencies are (1) establishing and maintaining shared understanding, (2) taking appropriate action, and (3) establishing and maintaining team organization. Furthermore, in (Cukurova, Luckin, Millán, & Mavrikis, 2018) an original method is presented to identify differences in students' SCP behaviors when participating in face-to-face practice-based learning (PBL). The framework uses students' nonverbal indices of physical interactivity (NISPI) to interpret key parameters of students' CPS competence. The results show that the NISPI framework can be used to accurately judge students' CPS proficiency levels based on their nonverbal behavioral data. For their part, in (Sun, et al., 2020) they constructed a generalized model of SCP competencies (i.e., skills and abilities) consisting of the core facets: shared knowledge building, negotiation/coordination, and team function maintenance. They validated their model in two empirical studies, with high school students playing an educational game and college students participating in a visual programming task via videoconferencing. Correlational analyses provided evidence for the orthogonality of the facets and their independence from individual differences in prior knowledge, intelligence, and personality, and regression analyses indicated that the facets predicted both subjective and objective outcome measures controlling for several covariates. In the study presented in (Andrews-Todd & Forsyth, 2020), they applied the on-task assessment framework to support the exploration of CPS skills at a deep level in an open-ended digital environment in which three students worked together to solve an electronics problem. The CPS construct was defined in depth prior to the implementation of the environment through the development of a complex, hierarchical ontology. The characteristics of the ontology were identified in the data and four theoretical profiles of collaborative problem-solver types were produced: high social/high cognitive, high social/low cognitive, low social/high cognitive, low social/high cognitive, and low social/low cognitive.

2.4.3 Monitoring and assistance of the collaborative process

Initially, works that in their research have used monitoring strategies in the learning process are presented, among them are: Hurtado and Guerrero (2006) who designed a collaborative learning activity for the teaching of Chemistry, through a computer tool that allows the teacher to create workgroups. The tool incorporates several positive interdependencies and has a module for monitoring the activities carried out by the students and is used by the teacher to control the process developed. Likewise, VPL (Virtual

Programming Lab), presented in (Rodríguez del Pino, Rubio Royo, & Hernández Figueroa, 2010) is a programming practice manager on Moodle, which allows incorporating the software development environment into the virtual classroom of the subject where it is used, enabling the delivery, editing, and execution of programming practices, in addition to the continuous and automatic monitoring of these. On the other hand, Persico et al. (2010) propose an approach to analyze learning processes in a computer-supported collaborative learning environment to support tutors in their monitoring tasks. The approach involves tracking interactions within the communication platform to identify signals of the participatory, social, cognitive, and teaching dimensions of the learning process. On the other hand, in a quasi-experimental study presented by (Kaendler, Wiedmann, Leuders, Rummel, & Spada, 2016) they focused on supporting teachers in monitoring interactions that, based on principles of educational psychology, made collaborative learning effective for knowledge construction, such as elaboration or monitoring of understanding, using videos of student interactions to illustrate these interactions, and allowing participants to practice monitoring. The results show that monitoring competence increased significantly in the group.

From the aspect of the design of collaborative activities, it is also necessary to consider monitoring elements to be incorporated, in this sense, some works that have focused on this are: Collazos et al. (2004) present design principles that are intended to be useful for teachers when evaluating and monitoring the collaborative learning process. They outline design principles that involve two aspects: teacher participation during the collaborative learning process and the inclusion of a strategy that generates conflict among group members. Similarly, Hermans et al. (2017) address how to design monitoring and evaluation arrangements for adaptive pathways that can support collaborative learning. By first reviewing the characteristics of adaptation pathway approaches and the challenges they pose for monitoring and evaluation. This approach is explored for its usefulness and feasibility in the case of adaptation pathway planning in Delta Programmers in the Netherlands.

On the other hand, not only collaborative learning should be monitored, it is necessary to monitor collaborative work as well, we found research such as: to design a performance management system in project-based collaborative enterprises, it is necessary to perform real-time monitoring of their business processes and activities. Shamsuzzoha et al. (2017) present a systematic approach to project business process monitoring (BPM) and identify the key aspects of virtual enterprise (VE) process evaluation. They elaborated fundamental metrics for defining business process performance monitoring. Similarly, Saiz, et al. (2005) to efficiently control and monitor the performance of virtual and extended enterprises highlight a performance monitoring and management system. Romero and Molina (2010) proposed a VBE reference model to execute and monitor VBE processes. Ferreira et al. (2012) presented a performance monitoring framework for a virtual organization to monitor different business processes. Schulte et al. (2012) described a virtual factory process monitoring framework by integrating service-oriented computing, the Internet of Things, and a business process management system.

Another important aspect to consider is the assistance that can be provided to the participants of the collaborative activities, according to this, research was analyzed as (Onrubia & Engel, 2012) a multiple case study that deals with the relationship between the assistance provided by the teacher during the collaborative process and the forms of collaborative work developed by groups of university students, in which two different types of macro-script are used. The results show two different patterns of teacher assistance in the two environments. These patterns differ in four dimensions, furthermore, the patterns are related to the forms of collaborative work that the groups develop (how the group is organized and how the written work is produced) within the imposed structural framework, in each setting. In the research presented in (Bottecchia , Cieutat, & Jessel, 2010), they defined a system that allows two remote parties to collaborate in real-time to successfully perform a mechanical maintenance task. They presented the T.A.C. (Télé-Assistance-Collaborative) which aims to combine remote collaboration and industrial maintenance. T.A.C. makes it possible to remotely "simulate" the co-presence of parts within the framework of a supervised maintenance task thanks to augmented reality (AR) and audio-video communication.

2.4.4 Comparison of related work

The following table (See Table 2.1) summarizes the characterization of the main previous studies, which were analyzed and subsequently allowed the extraction of information to establish each of the elements that the proposed process would contain.

Related work	Process definition	Collaborative work	Shared understanding construction	Measuring shared understanding	Collaborative problem-solving activities	Monitoring and assistance	Heterogeneous groups
(Granados, 2000)	NO	Learning	NO	Messages	YES	NO	NO
(De Haan, 2001)	NO	Learning	NO	Team interaction	YES	NO	NO
(Bittner & Leimeister, 2014)	YES	YES	ThinkLet "MindMerger"	Perception	NO	NO	YES
(Gomes, Tzortzopoulos, & Kagioglou, 2016)	Process Model	YES	Division of labor, coordinated perception, and mediated coupling	NO	NO	NO	NO
(Stein, et al., 2007)	NO	Learning	NO	Pattern of conversation	YES	NO	NO
(Cash, Dekoninck, & Ahmed-Kristensen, 2017)	NO	YES	Constant questions	NO	NO	NO	Homogeneous and heterogeneous
(Souren, Fang, & Dennis, 2018)	NO	YES	NO	Data model	NO	NO	NO
(Aubé, Rousseau, Brunelle, & Marques, 2018)	NO Moderated mediation model	YES	Mediating role	NO	YES	NO	NO
(Kniel & Comi, 2021)	NO	YES	NO	Perception	NO	NO	NO
(Margaret, 1994)	NO	YES	Perspective change, transaction management, and rapport-building	NO	NO	NO	NO
(Whitehead, 2007)	NO	YES	Model-based collaboration	NO	YES	NO	NO
(Coughlan & Macredie, 2002)	NO	YES - Requirements	Emerging collaborative approach	NO	NO	NO	YES
(Arikoglu E. , 2011)	NO	YES - Requirements	Scenarios and characters	NO	YES	NO	YES
(Werner, 2021)	NO	YES - Requirements	Best practices	NO	NO	NO	YES
(Varas, 2021)	NO	YES - Software development	NO	Visual prototype	YES	NO	NO
(Nakakawa, Van Bommel, Proper , & Mulder, 2018)	NO	YES - Architecture development	NO	NO	YES	NO	YES

(McKay, 1998)	NO	YES - Requirements	NO	Cognitive mapping	NO	NO	YES
(Hill, Song, Dong, & Agogino, 2001)	NO	YES - Software development	NO	Similarity of documents	YES	NO	YES
(McCarthy, O'Raghallaigh, Fitzgerald, & Adam, 2019)	NO	YES - Software development	Dynamic interaction	NO	YES	NO	NO
(Ingrid, Swaak, & Kessels, 2002)	NO	Learning	NO	Perception	NO	NO	YES
(Humayun & Gang, 2013)	NO	YES - Requirements	Clear organizational structure	Conceptual maps	YES	NO	YES
(Rosenkranz, Hummel, & Holten, 2016)	NO	YES - Software development	NO	Perception	YES	NO	YES
(Dossick, Osburn, & Asl, 2017)	NO	YES - Building design	NO	Photo elicitation techniques with ethnography	YES	NO	YES
(Sieck, Rasmussen, & Smart, 2010)	NO	YES	NO	Mental models, cultural models.	YES	NO	NO
(Smart, 2011)	NO	YES	NO	Assessment of shared skills	NO	NO	NO
(Berggren & Johansson, 2010)	NO	Learning	NO	Shared priorities	YES	NO	NO
(Rosenman, et al., 2018)	NO	Emergency medical teams	NO	Perception	YES	NO	YES
(Levesque, Wilson, & Wholey, 2001)	NO	Learning	NO	Mental models	YES	YES – Software tool	YES
(Redlich, Siemon, Lattemann, & Robra-Bissantz, 2017)	NO	Learning	Shared mental models	Perception	YES	NO	YES
(Quashigah, 2017)	NO	Learning	NO	NO	YES	YES – Virtual tool	YES
(Stewart, et al., 2019)	NO	Visual computer programming task	NO	NO	NO	YES - Videoconferencing software	YES
(Häkkinen, et al., 2017)	NO	Learning	NO	NO	YES	NO	YES
(Cukurova, Luckin, Millán, & Mavrikis, 2018)	NO	Learning	NO	Mental models	YES	NO	NO
(Sun, et al., 2020)	Model	Visual programming	NO	Perception	YES	NO	YES
(Rodríguez del Pino, Rubio Royo, & Hernández Figueroa, 2010)	NO	Programming practice	NO	NO	YES	YES - Moodle	NO
(Kaendler, Wiedmann, Leuders, Rummel, & Spada, 2016)	NO	Learning	NO	Perception	NO	YES - Software platform	NO
(Shamsuzzoha, Helo, & Sandhu, 2017)	NO	Virtual enterprise	NO	NO	NO	YES – Software tool	NO
(Onrubia & Engel, 2012)	NO	Learning	Mental models	NO	YES	YES – Moodle	YES

Table 2.1 Characterization of related works

The first part of the related works describes those works in which shared understanding is investigated, specifically those works that seek the achievement of shared understanding, works that focus on the specific context of software engineering, and works that have focused mainly on the measurement of this shared understanding are also shown. In addition, papers that have investigated problem-solving activities and monitoring and assisting collaborative processes are also analyzed. As can be seen in the comparison table, there are a number of studies in these areas, however, it is striking that none of these studies uses or defines a process that establishes, step by step, what to do and how to build a shared understanding, as is the case of the THUNDERS process, the process proposed in this research project, which is intended to serve as a guide to support the entire collaborative process, from the design of the collaborative activity, its execution and the validation of the performance of the participants and the resolution of the problem posed, including elements to achieve a shared understanding specifically in problem-solving activities with heterogeneous group formation and its respective measurement in two specific moments when understanding the collaborative activity and at the end of its execution. It also contains elements of monitoring and assistance to facilitate the application of the entire process.

2.5 Systematic literature review

As defined above, one of the main problems of collaborative work is that successful collaboration is difficult to achieve (Grudin, 1988). Furthermore, considering Rummel and Spada (2005) who argue that collaboration does not occur as easily as one might expect, there is a need to find a way to promote it and seek to achieve it when executing a collaborative activity. That is why in this project improving participants' communication through shared understanding is sought and that as a consequence better collaboration is achieved, considering that shared understanding is crucial for effective collaboration (Bittner & Leimeister, 2014) in addition considering that shared understanding, as a process, is the basis of the collaborative act (Gomes, Tzortzopoulos, & Kagioglou, 2016). However, an underlying theory of shared understanding has not yet been developed, this topic has been superficially addressed in studies on social mind and team cognition in psychology, which are based on the concept of understanding, but it should be considered in the field of social interaction in collaborative design and collaborative activities (Bertelsen, 2003). That is why initially, in order to propose a process to guide step by step the achievement of this shared understanding in collaborative activities, a Systematic Literature Review (SLR) has been conducted, where we seek to characterize and identify the definitions, approaches, and importance of shared understanding existing and proposed in the literature, in order to subsequently define a complete process that takes into account the elements analyzed in this review.

A SLR is conducted as a study, where it is proposed to identify, analyze and interpret relevant primary studies related to a specific research question (Wohlin, Höst, & Henningsson, 2003), considering the following activities: planning, conducting and reporting, as established by Kitchenham and Charters in (2007).

2.5.1 Planning the review process

This section presents the planning of the literature review, which includes two main parts: first, the objective of the research, the specification and structure of a set of research questions, and sub-questions that will guide the review and the data to be obtained from the reviewed papers. The second part defines the protocol, which determines how the review will be carried out, including the selection of data sources, the definition of the search chain with each of its elements, and the inclusion and exclusion criteria that determined which information was considered or not.

2.5.1.1 Systematic literature review research questions

The general objective of the review was to characterize and identify, according to the literature, those existing approaches that define, measure, and analyze the importance of shared understanding in order to verify the characteristics and analyze their inclusion as part of the process specification. For the previous objective, a set of research questions was specifically defined, which can be seen in Table 2.2.

Research questions	
Q1: How is shared understanding defined?	**Q1.1**: Is there a formal definition of shared understanding?
	Q1.2: Is the shared understanding defined in moments, phases, elements, or parts?
	Q1.3: Does the definition of shared understanding depend on the context in which it is applied?
Q2: How can shared understanding be measured or recognized?	**Q2.1**: Is there a formal definition of indicators to measure or recognize shared understanding?
	Q2.2: Are there metrics to measure indicators of shared understanding?
	Q2.3: How were these indicators validated?
	Q2.4: Depending on the context in which the shared understanding is built, are there different types of indicators?
	Q2.5: What types of tools, strategies, mechanisms, or methods allow the application of these indicators to measure shared understanding?
Q3: Are there any tools/strategies to measure/recognize shared understanding?	**Q3.1**: What is the context of application or validation of the tools/strategies?
	Q3.2: At what point in the activity is it proposed to measure shared understanding?
Q4: Why is shared understanding important?	**Q4.1**: What are the positive effects of shared understanding?
	Q4.2: In what contexts is it most important to achieve shared understanding?

Table 2.2 SLR research questions

2.5.1.2 Systematic literature review protocol

The data sources used for the development of the SLR were: IEEE Computer Society Digital Library, ACM Digital Library, and Scopus. In the process of defining the search strategy, the keywords were initially identified with their respective synonyms and plurals, which are shown in Table 2.3 and then the search string was defined with them.

Term	Key words	Synonymous
A	Shared understanding	Understanding in common, shared mental models
B	Meaning	Definition, concept
C	Measure	Measuring, measurement, detecting, recognize

Table 2.3 Key words, synonyms, and related words

By combining these keywords and their synonyms, using AND & OR connectors, the search string was developed, defined as:

(("shared understanding" OR “understanding in common” OR “shared mental models”) AND (meaning OR definition OR concept) AND (measure OR measuring OR measurement OR detecting OR recognize))

To carry out the selection of studies, first, it was determined that the time range for the search was papers published up to 2018. Inclusion and exclusion criteria were also defined to verify the quality of papers and to ensure that they were approaches and studies related to the SLR objective. The inclusion and exclusion criteria are shown in Table 2.4. and Table 2.5 respectively.

ID	Inclusion criteria
IC.1	The study addresses the definition and/or measurement of shared understanding
IC.2	The study is in English
IC.3	The study is published in conference proceedings, journals, or workshops
IC.4	The full text can be accessed

Table 2.4 Inclusion criteria

ID	Exclusion criteria
EC.1	The study refers to shared understanding (or uses the term) but does not focus on discussing what it is, what it is implied, how it can be measured, how it is composed, how it can be achieved, etc.
EC.2	The study is not a scientific paper (editorials, prefaces, interviews, news, reviews, discussions, debates, comments, summaries of tutorials, panels, and poster sessions)
EC.3	The study is not written in English
EC.4	The study is a systematic literature review
EC.5	The full paper is not accessible

Table 2.5 Exclusion criteria

2.5.2 Execution of the review process

This section presents the main steps to carry out the SLR that was previously planned. The main steps were: identification and selection of primary studies, data extraction, and characterization and synthesis of the primary studies.

2.5.2.1 Identification and selection of primary studies

The identification and selection of primary studies was based on two main steps. Step 1: Search for studies in the data sources and step 2: apply the inclusion and exclusion criteria to the results obtained.

Step 1: This consisted of applying the search strings to each of the data sources, thus retrieving the following number of papers: 30 in IEEE, 120 in ACM, and 220 in Scopus. In this step, a debugging process of the retrieved studies was also carried out, which consisted of identifying repeated studies and others that were considered garbage because they did not correspond to the description of a paper. Table 2.6 summarizes the results of applying this first step.

Digital Library	Results	Trash and repeated	Filtered results
IEEE	30	20	10
ACM	120	40	80
Scopus	220	37	183
Total without the debugging process	**370**	**Total with the debugging process**	**273**

Table 2.6 First step results

Step 2: To reduce the subjectivity of the application of the inclusion and exclusion criteria, several researchers participated in this step (two from the Universidad de la Plata and one from the Universidad del Cauca). In the first iteration of this step, the application of the criteria was done by reading the title of the paper, the abstract, the keywords, and the conclusions. The researchers were in charge of reading the selected sections of the 273 papers, and at the end, a meeting was held where each researcher presented their results, and in those papers that did not have the same classification of inclusion or exclusion, the reasons for the decision taken were presented, and subsequently, a consensus was reached among all participants.

As a result of this first iteration, **30** papers were included as possible primary studies. A second iteration was performed, where the criteria were applied by reading the complete content of these **30** papers. In this iteration, the researchers maintained the same review dynamics as in the first iteration to reach a consensus. At the end of this iteration, a set of **21** papers was obtained, defined as the primary papers.

Table 2.7 shows the set of 21 primary studies. The data shows that 9 of these studies were published in conferences (C), 1 in workshops (W), and 11 in journals (J).

#	Year	Publication	Reference	#	Year	Publication	Reference
1	2018	J	(Ernst, McComb, & Ley, 2018)	12	2014	W	(Braunschweig & Seaman, 2014)
2	2018	J	(Rosenman, et al., 2018)	13	2014	C	(Munson, Kervin, & Robert Jr., 2014)
3	2017	C	(Anindi, Rochintaniawati, & Rafikah Agustin, 2017)	14	2013	C	(Lv, Zhao, Chen, & He, 2013)
4	2017	J	(Berggren, Johansson, & Baroutsi, 2017)	15	2012	C	(Bondarl, Katzy, & Mason, 2012)
5	2017	J	(Oppl, 2017)	16	2011	J	(Haavik, 2011)
6	2017	J	(Gulgun, 2017)	17	2010	C	(Arikoglu, Blanco, Pourroy, & Hicks, 2010)
7	2017	J	(Abraham, et al., 2017)	18	2010	C	(Berggren & Johansson, 2010)
8	2016	J	(Kim & Shah, 2016)	19	2007	C	(Evermann, Haggard, & Ferreira, 2007)
9	2016	C	(Berggren P. , Johansson, Allard, & Torensjö, 2016)	20	2007	J	(Salas, Rosen, Burke, Nicholson, & Howse, 2007)
10	2015	J	(Rosen, 2015)	21	2002	J	(Mulder & Swaak, 2002)
11	2014	C	(Jentsch, Beimborn, Jungnickl, & Renner, 2014)				

Table 2.7 Primary Studies

2.5.2.2 Data extraction

Data extraction was performed by completing a spreadsheet that allowed us to collect important information from the 21 primary studies. In this way, the specification of common attributes of the studies was performed, such as year, authors, title, source, and type of event where it was published; and also specific information that made it possible to answer the research questions.

Table 2.7 shows the distribution of the 21 primary studies from 2002 to 2018. Figure 2.3 shows the distribution of publications by year and type of publication (conference, workshop, journal), from which it can be highlighted that most of the publications were made during the last six years. Figure 2.4 shows the percentage of each type of publication, highlighting that 52.4% of the primary studies were published in journals and 42.9% in conferences, and 4.7% in workshops.

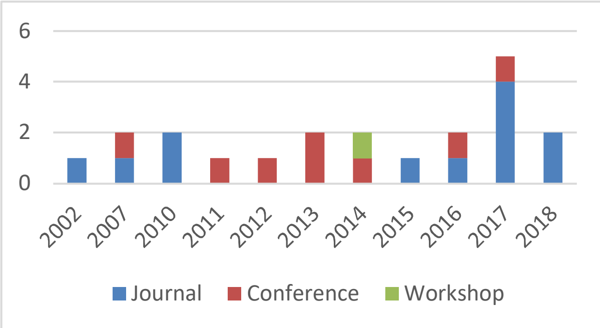


Figure 2.3 Papers distribution by year

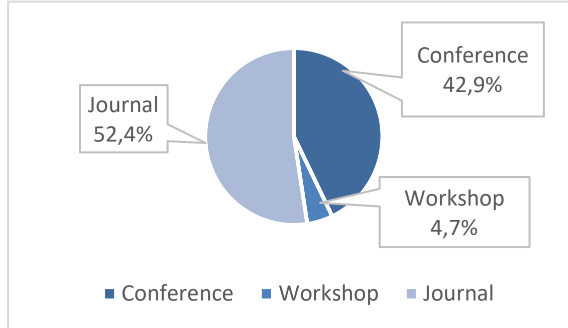


Figure 2.4 Type of publication

In addition to this information obtained, the analysis of these primary studies answered each of the research questions as shown below.

Q1.1: Is there a formal definition of shared understanding?

There are several definitions of the shared understanding (SU) given by different authors and after reviewing the primary studies, it was possible to analyze them and they are presented below: For the project presented in (Ernst, McComb, & Ley, 2018), the concept of SU was aligned with the literature on shared mental models (SMM), which are context-dependent individual knowledge structures that help team members to function collaboratively (McComb, et al., 2012), furthermore, it was analyzed that, individuals' SMMs converge towards shared mental models when team members interact or when they are explicitly guided by education and training, in this sense, the construction of SU is achieved through communication and good individual preparation prior to communication, which allows generating questions and adequate conversation. Furthermore, for (Rosenman, et al., 2018), team situational awareness (TSA) is conceptualized at the individual, team, and organizational levels, which is the shared understanding among team members that facilitates team coordination and task performance. TSA supports dynamic decision-making and adaptability in unpredictable and time-pressured situations and is shown to improve team effectiveness. Similarly, SU has been defined as the ability to exploit causal bodies of knowledge to achieve cognitive and behavioral goals (Bittner & Leimeister, 2014), in this sense, it is difficult to find objective, easy-to-use, and easy-to-understand assessment methods to measure shared understanding in teams. In (Kim & Shah, 2016) argue that SU is "the overlap of understanding and concepts among group members” (Mulder & Swaak, 2002), "the ability to coordinate behaviors toward common goals or objectives” (Smart, et al., 2009), and "having mutual knowledge, mutual beliefs, and mutual assumptions (content and structure) about the task” (Clark & Brennan, 1991), they also define SU as a state of group consensus resulting from the culmination of an entire discussion. In addition to representing an alignment of mental states (Mulder & Swaak, 2002), similarly, assessing levels of SU through natural dialogue is a challenging task, because the human dialogue is complex: discussions go in cycles, agreements are fluid and proposals of ideas are often communicated and accepted implicitly, which makes it challenging to assess (Di Eugenio, Jordan, Thomason, & Moore, 2000).

Q1.2: Is the shared understanding defined in moments, phases, elements, or parts?

According to the review performed to each of the primary studies, it was determined that most of them do not divide SU into moments, phases, elements or parts, some of them specify some steps to reach its construction, which we show below: The objective of the work presented in (Oppl, 2017) was to provide a methodology that would offer a structural and procedural guide for conceptual modeling to support the collaborative construction of SU (Hevner, March, Park, & Ram, 2004) (Aken, 2004). In this sense, CoMPArE is an approach for collaborative articulation and alignment of individual understandings about collaborative work processes using conceptual modeling techniques, which serve as externalized artifacts that represent participants' mental models and thus act as mediators for the development of a SU (Groeben & Scheele, 2000). CoMPArE is a two-step modeling approach, the first ensures that each participant can contribute their individual point of view on the work process, and the second aims to avoid unreflective acceptance of inconsistent or conflicting views by explicitly confronting participants with these issues. For their part, in (Kim & Shah, 2016) analyzed the process of how SU is achieved, relying on what was defined by Mulder et al. (2002) who described this process as a three-step transition from an initial conceptual learning phase (primary exchange, reflection, and refinement of facts and concepts) to a feedback phase (confirmations, verifications, and explanations among group members) and, finally, to a motivation phase (evaluative expressions of usefulness, certainty, and uncertainty). While on the other hand, Bossche et al. (2011) identified a set of team learning behaviors and explained that collaborative groups express and listen to individual understandings (construction), discuss and clarify to reach a mutual understanding (construction), and negotiate an agreement on a mutually shared perspective (constructive conflict), this as steps to reach the construction of an SU. Similarly, Eugenio et al. (2000) described the process of achieving a SU as a three-phase transition between the stages of balancing, proposing, and disposing and also emphasized the importance of following the dynamics of compromise among team members.

Q1.3: Does the definition of shared understanding depend on the context in which it is applied?

Considering the reviews of the primary studies, it was determined that there is no specific or different definition of SU depending on the context in which it is used. All the studies maintain the idea that SU refers to a similarity or agreement of perceptions between a group of people on the topic worked on, and that it is applied or used in different contexts as shown below: in the healthcare context, for example (Abraham, et al., 2017) defined that the degree of SU between residents and nurses regarding a patient can be, at least partially, traced to the degree of coincidence in their handover communication content. The development of this SU can lead to a better communication foundation, potentially leading to better outcomes related to care coordination, communication, and continuity of care. In this regard, differences in clinical content may be due in part to different clinical roles in the delivery of patient care and management practices that require different perspectives to ensure comprehensive care. However, these contents can be explicitly reinforced during handoff conversations, creating opportunities to enhance the SU in relation to a patient. Similarly, the project presented in (Ernst, McComb, & Ley, 2018) sought to communicate and build an SU of patient conditions by communicating information about the patient's health, family, and social conditions, the goal was to achieve a SU among nurses of the patient's condition while doing a shift change with incoming nurses. In order for them to have this understanding, the idea was to be able to have this information clear and not be distorted at shift change.

Besides, in the educational context, for (Anindi, Rochintaniawati, & Rafikah Agustin, 2017), a low SU is due to low discussion among group members, in addition to the existence of group members who do not participate, and those groups in which they do not care about the understanding of all, there are no adequate results of the task to be performed. Similarly, it was identified that if the size of the group is increased, there are fewer opportunities and less time for members to communicate, and they do not generate good results. For (Rosen, 2015), in the case of collaborative problem-solving (CPS) it is required that students are able to establish, monitor, and maintain SU throughout the problem-solving task, responding to requests, sending important information about the tasks performed, establishing or negotiating shared meanings, verifying what each knows, and taking action to repair deficits in SU, which can be viewed as an effect if the goal is for a group to build the common ground needed to perform well together, or as a process by which peers make a conceptual change (Dillenbourg, 1999). And finally, Gulgun (2017), defines that in computer-supported collaborative learning, learning is characterized as a process of collective meaning-making mediated by ICT technologies in which different perspectives are negotiated and refined toward a common goal in interaction (Stahl, Koschmann, & Suthers, 2006). Co-constructing a joint problem space (Sarmiento & Stahl, 2008) and achieving reciprocal perspectives toward shared constructs in a shared space (Zemel & Çakir, 2009) are vital to the success of collaborative learning. Providing tools that help collaborators develop that level of SU is an important design goal.

On the other hand, in other types of contexts, for (Oppl, 2017), the existence of a SU of a collaborative working process among all stakeholders is a prerequisite for its successful implementation, which is facilitated when stakeholders make their individual views explicit and create externalizations that can be used as topics of discourse. Similarly, SU between business and IT units has been discussed frequently and in a wide range of fields in research (Jentsch, Beimborn, Jungnickl, & Renner, 2014), although they still lack a coherent and comprehensive conceptualization and operationalization of what business-to-IT SU (B/IT-SU) is. In (Lv, Zhao, Chen, & He, 2013) analyzed that SU represents the degree of consistency of understanding of the role of Information systems in the organization between IT and business professionals. Lind and Zumd (1991) consider SU (in terms of convergence), as an understanding of the importance of business processes and technology support for the business between technology providers and users. Consensus between both parties means that they have the same understanding of the importance of some issues.

Q2.1: Is there a formal definition of indicators to measure or recognize shared understanding?

According to the primary studies reviewed, it can be analyzed that the existence of indicators to measure SU is very scarce. Most of the studies analyzed show metrics to measure without considering specific indicators for building or not building this understanding. Below are the indicators that have been defined: In (Munson, Kervin, & Robert Jr., 2014) defines an indicator of mutual attraction, or SU, as the trust and performance of teams, whose members communicate in person, by email, and through other channels. This assessment was conducted in a master's course at the University of Michigan School of Information. In this course, students were assigned to groups of four to six students, analyzing the following indicators of SU, among the written interactions they conducted within the group: higher Latent Semantic Similarity correlates with higher SU in teams, a lower proportion of first-person plural pronouns correlates with higher SU, and a higher number of words, in general, correlates with higher SU.

Q2.2: Are there metrics to measure indicators of shared understanding?

Within the primary studies analyzed, there are no specific metrics for the defined indicators, only general metrics are defined to determine the level of SU building within an activity, as shown below: In (Rosenman, et al., 2018) the team situational awareness (TSA) agreement metric was used, which is obtained by averaging the pairwise agreement for each dyad in a team and then averaging across dyads to produce a team-level agreement. Measures of perceived SU and team leadership effectiveness were defined, where individual team member scores were aggregated within the team to create a single score. In (Berggren, Johansson, & Baroutsi, 2017) measures called Shared Priorities are used for the measurement of SU, which is based on the ranking of self-generated strategic items, it was also used with other well-documented measures of team knowledge-based on self-assessment. The shared priorities measure is based on the idea that (1) Team members individually generate five items that are important for the team to achieve its shared goal. (2) Each team member individually ranks his or her own item in order of importance. (3) The researcher collects the lists. (4) The investigator scrambles the order of the items on a list. This is repeated for all lists. (5) The investigator distributes the lists among the members (except the team member's own list). (6) All team members sort the list items in order of importance for all lists. (7) The researcher calculates Kendall's concordance measure for all lists (Kendall, 1975) i.e., the extent to which team members have ranked the items similarly. In the project shown in (Berggren P. , Johansson, Allard, & Torensjö, 2016) two studies are presented, the first one student participated in a micro world experiment in which they tried to rank predetermined factors to measure SU. In the second study, Swedish Armed Forces officers participated in an exercise in which they ranked self-generated factors. They demonstrate how a measure of shared priorities became a usable and tractable measure of team SU by using lists of factors that subjects had to rank in order of perceived importance. The dependent variables were simulation performance, the CARS, which was an 8-question self-assessment (McGuinness & Foy, 2000), mutual awareness (DATMA) (MacMillan, Paley, Entin, & Entin, 2005), which consisted of three parts: team workload awareness, task awareness, and teamwork assessment. On the other hand, a computational model for automatic prediction of consistency between team members' understanding of their group's decisions was presented in (Kim & Shah, 2016) which uses dialogue features focused on the dynamics of group decision making. In order to develop an intelligent system that monitors meetings and provides useful feedback to help team members stay "on the same page". When the outcome is binary, i.e., team members may have a consistent or inconsistent understanding of group decisions. They use a particular set of traits defined by Eugenio et al. (2000), which has been shown to control the evolving attitude of participants' commitment to the options presented during a meeting. Eugenio's features are dialogue act (DA) types (Stolckel, et al., 2000), (Ji & Bilmes, 2005), which are semantic labels that define the functional roles of utterances. A DA expresses the underlying intention of the speaker's discourse. For (Evermann, Haggard, & Ferreira, 2007) the project presented a measure of measuring mutual understanding between different stakeholder groups in system development based on a development artifact (BML class diagrams). Accordingly, understanding is demonstrated not by a memory recall, but by the application of knowledge to problems beyond those used for training, where a set of individual multiple problem-solving questions on the development artifact was subsequently used. For their part, (Mulder & Swaak, 2002) developed a coding scheme for assessing group learning and SU. Both the conceptual model and the coding scheme were employed in an empirical study, in a globally distributed engineering team. They used a variety of data sources, methods to collect rich, qualitative data, and numerical and quantitative data, including observations, transcripts, interviews, questionnaires, rating scales, weekly communication diaries, tracking of system use, and expert judgment of performance. They added a self-rating instrument (Mulder, 1999) to measure the perception of a SU (both process and product). With this instrument, they measured how group members perceived their understanding of the content, procedure, and related aspects. Using a 6-point scale to measure how the understanding was at a given point in time.

Other studies used the perception of the participants on the achievement or not of the SU, among them are: In the work presented in (Oppl, 2017), the perceptions of the participants on the adequacy of the approach to facilitate the development of a work process SU, and the adequacy of the modeling outcome with respect to the individually perceived work process were analyzed, in addition, a feedback questionnaire was designed to evaluate the outcome of the workshops evaluated, each item was evaluated on a five-point Likert scale, and were complemented with open questions to allow free comments and articulation of impressions. For its part, the project (Rosenman, et al., 2018), used the Team situational awareness (TSA) to measure participants' perception of the SU (with a multiple-choice question within the questionnaire), in addition to measuring clinical team, team leader effectiveness and team experience. In (Abraham, et al., 2017), audio-recorded resident and nurse handoff communication on the general medicine floor of an academic hospital, where they measured semantic similarity, a proxy for content overlap, between resident-resident and nurse-nurse communication. They also used several steps: a qualitative conversational content analysis; an automated semantic similarity analysis using reflexive random indexing (RRI); and comparing the semantic similarity generated by the RRI analysis with human ratings of semantic similarity, in order to analyze overlap in communication content. Similarly, in (Jentsch, Beimborn, Jungnickl, & Renner, 2014), developed a tested content validity survey instrument that measures the degree of business/IT SU in a multifaceted manner. They adopt an innovative content validation method by comparing survey results with data from a cognitive measurement approach (Repertory Technique).

Q2.3: How were these indicators validated?

According to the studies analyzed, since there are no specific indicators to measure SU, they have not been validated. But each of the metrics or measures shown above have been validated in different projects, case studies, or experiments, which has allowed finding gaps, and improvements for each of them. In addition, the contexts vary between healthcare (Ernst, McComb, & Ley, 2018), (Rosenman, et al., 2018), (Abraham, et al., 2017), (Kim & Shah, 2016), (Berggren P. , Johansson, Allard, & Torensjö, 2016), education (Anindi, Rochintaniawati, & Rafikah Agustin, 2017), (Rosen, 2015), (Braunschweig & Seaman, 2014), (Munson, Kervin, & Robert Jr., 2014), (Berggren & Johansson, 2010), (Mulder & Swaak, 2002), and collaborative work (IT, requirements engineering, and collaborative tasks) (Berggren, Johansson, & Baroutsi, 2017), (Oppl, 2017), (Gulgun, 2017), (Jentsch, Beimborn, Jungnickl, & Renner, 2014), (Lv, Zhao, Chen, & He, 2013), (Bondarl, Katzy, & Mason, 2012), (Haavik, 2011), (Arikoglu, Blanco, Pourroy, & Hicks, 2010), (Evermann, Haggard, & Ferreira, 2007), (Salas, Rosen, Burke, Nicholson, & Howse, 2007).

Q2.4: Depending on the context in which the shared understanding is built, are there different types of indicators?

Analyzing the primary studies, it was possible to determine that the SU is not constructed or achieved differently depending on the context in which it is applied, as previously mentioned, it is a reference base among group members (Ernst, McComb, & Ley, 2018), (Oppl, 2017), (Kim & Shah, 2016), (Salas, Rosen, Burke, Nicholson, & Howse, 2007), (Mulder & Swaak, 2002), which serves for better collaboration and is independent of the context, for this reason, there are no indicators that depend on it (Ernst, McComb, & Ley, 2018), (Berggren, Johansson, & Baroutsi, 2017), (Braunschweig & Seaman, 2014).

Q2.5: What types of tools, strategies, mechanisms, or methods allow the application of these indicators to measure shared understanding?

Analyzing the primary studies, it could be determined that, specifically, the tools, strategies, mechanisms, or methods to measure SU, are applied to make use of the specified metrics or measures, considering that the main indicator is the achievement or not of SU in a group of people working around a collaborative task. For example, in (Ernst, McComb, & Ley, 2018) a questionnaire was used to measure the degree of similarity of shared mental models, and the Patient Knowledge Assessment Tool questionnaire was used to measure the shared clinical understanding of pediatric cardiology patients, which was developed and validated through the handover of their specialist physicians. This instrument, modified for the clinical practice of the nursing unit, made it possible to assess the degree of similarity in Shared Mental Models (SMM) between two nurses regarding the patient's condition. Similarly, in

(Braunschweig & Seaman, 2014) developed and evaluated a technique to measure the degree of SU and identify areas of similarity and difference. Adapted from the Pathfinder technique for assessing teams' mental models, it is a quantitative pairwise comparison analysis of design concepts as understood by the team. They conducted an empirical mixed-methods pilot study of the technique with 5 student teams developing a project. They used questionnaires and interviews to assess the effectiveness of the technique in measuring areas of similarity and difference. The procedure consisted of selecting concepts from the design on which the team is working, collecting the team's relationship ratings through a questionnaire, and then calculating the similarity of understanding of the concepts. On the other hand, to validate the approach presented in (Oppl, 2017), a joint working group was used in the course of a modeling workshop, with 175 participants. The observable effects during that process could be evaluated by applying a variant of discourse analysis, adapted to collaborative modeling environments, which was analyzed through the dimensions, participation, epistemic, argumentative, social modes of construction and modeling dimensions. For their part, Wildman et al. (2014) have identified six main methods of data collection used in team-based research specifically to measure SU: (1) interview transcripts, (2) communication transcripts, (3) video recordings of behavior, (4) direct observations of behavior, (5) self-reported perceptions of team cognition, and (6) self-reported individual knowledge.

Table 2.8, below shows each of the primary studies with their respective strategy or mechanism for measuring SU.

Paper number	Measurement strategy	Paper number	Measurement strategy
1	Mental models	12	Mental models, perception questionnaire
2	Perception questionnaire	13	Conversational analysis, perception questionnaire
3	Observer questionnaire	14	Perception questionnaire
4	Shared Priorities	15	Perception questionnaire
5	Perception questionnaire	16	Observer questionnaire, interviews
6	Observer questionnaire	17	Individual representations
7	Conversational analysis, analysis of audio recordings	18	Shared priorities
8	Computational model, individual summaries, perception questionnaire	19	BML questionnaire, class diagrams
9	Shared priorities	20	Mental models
10	Computer agent, question analysis	21	Observations, transcripts, interviews, questionnaires, rating scales, weekly communication diaries, monitoring system usage, expert judgment of performance, self-appraisal
11	Conversational analysis		

Table 2.8 Strategies for measuring the shared understanding of each primary paper

Q3.1: What is the context of application or validation of the tools/strategies?

As could be seen in the primary studies, there are different contexts in which the concept of constructing SU is used, some of those contexts analyzed are: in the educational context, in a public secondary school in Bandung (Anindi, Rochintaniawati, & Rafikah Agustin, 2017), 39 eighth grade students had to perform a collaborative problem solving activity that consisted of constructing an interactive animation, from this activity 11 aspects were measured: 1) discovering team members' perspectives and skills, 2) discovering the type of collaborative interaction required and setting goals, 3) understanding problem-solving roles, 4) constructing a shared representation and negotiating the meaning of the problem, 5) identifying and describing the tasks to be performed, 6) communicating with team members about actions taken, 7) executing plans, 8) following up on commitment roles, 9) monitoring and repairing the SU, 10) tracking the results of the action and evaluating success in solving the problem, 11) monitoring, feedback and adaptation of the organization and team roles. This evaluation was carried out by means of a questionnaire filled out by an observer who determined, based on the actions of the groups, the corresponding evaluations.

In the healthcare context, in the project presented in (Kim & Shah, 2016), each team of two participants acted as first responders in a hypothetical emergency scenario. Their goal was to develop a plan to transport several injured patients to hospitals. Due to the limited number of transports, participants had to prioritize patient handoffs and determine ideal travel routes. The tool analyzed team chat in real-time and applied a set of experimental treatments during the planning process. During Phase 3, participants completed individual post-meeting summaries, writing detailed descriptions of the plan for each of their discussion topics, which were reviewed by annotators to objectively measure the consistency of understanding. Participants also responded to post-experiment questionnaires, in which they offered subjective evaluations of perceived SU and suggested usefulness of the review. On the other hand, the project (Ernst, McComb, & Ley, 2018) sought to communicate and construct a SU of patients' conditions by communicating information about the patient's health, family, and social conditions. Initially, nurses individually prepared for the handoff by gathering their thoughts and organizing their knowledge about the change into a concise narrative. To maximize the effectiveness of the digital companion, nurses on a unit were to share a teamwork SMM for the role of the electronic health record (EHR) in handoffs, defining what information was to be delegated to the computer for storage and communication. Similarly, in (Ernst, McComb, & Ley, 2018) and in (Rosenman, et al., 2018) were validated in the context of patient information transfer, in a hospital setting. Where the idea was to communicate patient-related status and information between nurses, interprofessional emergency medical teams, emergency medical residents, and medical students, in order to understand the information provided between staff, in order to provide them with better treatments.

For another teamwork context, in order to have a controllable, but a relevant environment to evaluate the usefulness of the Shared Priorities measure, in (Berggren, Johansson, & Baroutsi, 2017) have chosen to use a microworld called C3 Fire. Twelve teams participated with three members in each, six trained and six untrained. Each participant chose a role to play and each of them complemented the other, individually they could not act. On the other hand, in (Rosen, 2015) a computer-based collaborative problem solving (CPS) assessment task, the student was asked to collaborate with a partner (computer-driven agent or a classmate) to find the optimal conditions for an animal in the zoo. The task was designed to measure the student's CPS skills to establish and maintain an SU, take appropriate actions to solve the problem, monitor progress, and provide feedback to the partner. For the measure, a computer agent was programmed to act with different features relevant to the CPS dimensions: problem-solving, SU, and group organization. The SU interaction focused on the agent's responses to the learner's rationale questions.

Figure 2.5 shows, according to the primary studies analyzed, the summary of the contexts in which research has been conducted on SU for each year, where it can also be seen that in general terms the context where most studies have been conducted is in collaborative work (activities in which work is done in groups to carry out a collaborative activity), where 8 studies have been conducted, followed by 7 studies in the area of education, 4 studies in the area of health, 1 in requirements, and 1 in business.

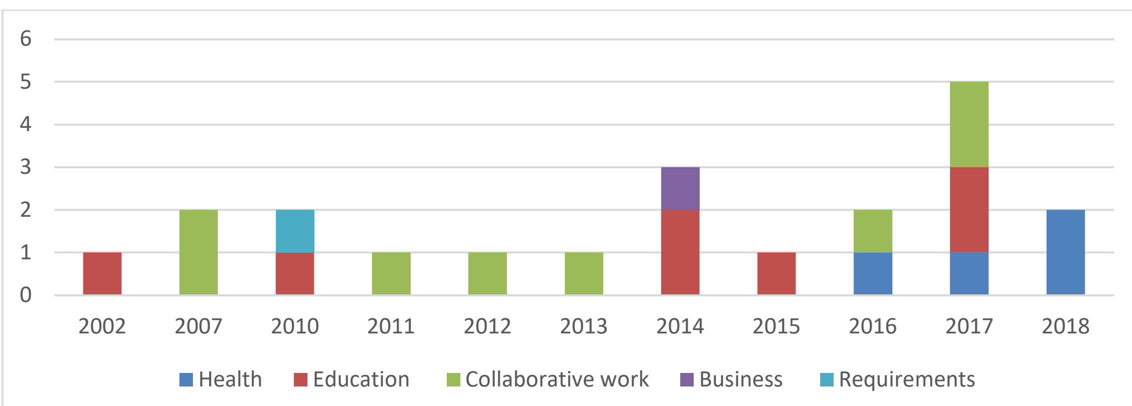


Figure 2.5 Summary of the research contexts on shared understanding for each year

Q3.2: At what point in the activity is it proposed to measure shared understanding?

Considering the primary studies reviewed, it can be said that most of them measure SU at the end of the collaborative activity, in order to validate that at the end, everyone agrees on what has been done, that everyone has an understanding of what has been done and that they also consider that the objective of the task has been fulfilled. The projects that consider so are: (Ernst, McComb, & Ley, 2018), (Rosenman, et al., 2018), (Anindi, Rochintaniawati, & Rafikah Agustin, 2017), (Oppl, 2017), (Abraham, et al., 2017), (Kim & Shah, 2016), (Jentsch, Beimborn, Jungnickl, & Renner, 2014), (Braunschweig & Seaman, 2014), (Munson, Kervin, & Robert Jr., 2014), (Lv, Zhao, Chen, & He, 2013), (Bondarl, Katzy, & Mason, 2012), (Haavik, 2011), (Berggren & Johansson, 2010), (Evermann, Haggard, & Ferreira, 2007), (Salas, Rosen, Burke, Nicholson, & Howse, 2007).

On the other hand, there are those projects in which they perform a measurement of the achievement of SU at the beginning of the collaborative activity, where they are interested that all group members understand what they should do in the activity, what is the problem to solve or what is the objective to achieve in the collaboration. Once this is understood, they can work in a better way and be focused on achieving what has been requested. In this regard, those projects that do so are: (Berggren, Johansson, & Baroutsi, 2017), (Gulgun, 2017), (Braunschweig & Seaman, 2014).

In this review, in addition, there is a project that performs validation in both moments described above, they are interested in determining if everyone understood the objective of the activity and at the end of the activity, if everyone understood what was done: (Arikoglu, Blanco, Pourroy, & Hicks, 2010).

And finally, there are those projects in which they carry out a measurement at the beginning, during the activity they are monitoring that the understanding between the members of the group is not lost and also at the end of the collaborative activity: (Rosen, 2015), (Mulder & Swaak, 2002).

The following figures show the distribution of each of the primary studies analyzed, determining at what point in the collaborative activity the measurement of SU is performed. Figure 2.6 shows the distribution for each year, and in Figure 2.7 shows that 71.4% of the papers measure SU at the end of the activity, 14.3% at the beginning, 9.5% at the beginning, during and at the end, and finally 4.8% at the beginning and at the end of the activity.

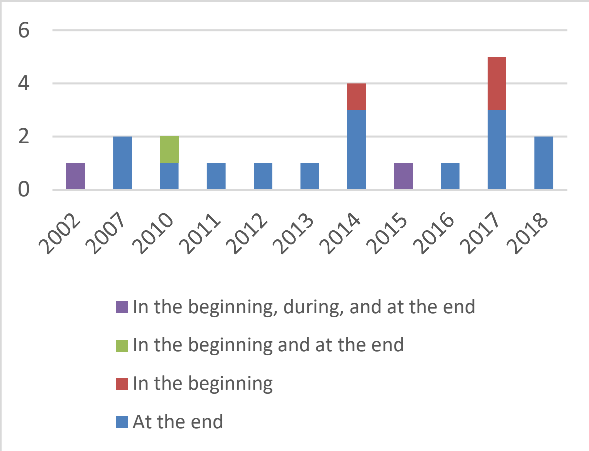


Figure 2.6 Distribution of papers for each year

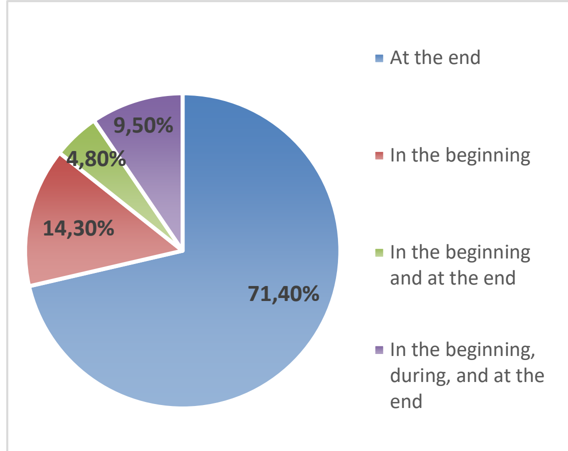


Figure 2.7 Percentage of shared understanding measurement moments

Q4.1: What are the positive effects of shared understanding?

As mentioned above, the positive effects and benefits of building SU among members of a group working in a collaborative activity are several, however, shown below are those that have been named in the primary studies that have been analyzed. For (Berggren, Johansson, & Baroutsi, 2017) determined that for a team to be successful, team members must have a good understanding of the different roles in the team, the assumptions of each other's knowledge about the other team members' understanding of the situation, and including interpersonal relationships, often referred to as 'shared awareness', 'team consciousness' (Smart, et al., 2009), or 'shared team mental models' (DeChurch & Mesmer-Magnus, 2010). On the other hand, for (Kim & Shah, 2016), SU has positive effects on production performance (both in terms of product quality and quantity) (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000), individual satisfaction (Langan-Fox, Anglim, & Wilson, 2004), reduction of iterative loops and (Kleinsmann, Bujis, & Valkenburg, 2010), and team morale (Darch, Carusi, & Jirotka, 2009). Furthermore, for (Jentsch, Beimborn, Jungnickl, & Renner, 2014), research has shown that SU between business and IT (B/IT-SU) is crucial for its success. Thanks to a high level of B/IT-SU, companies achieve greater knowledge integration and satisfaction in joint teams and achieve a higher level of performance and strategic alignment between business and IT. According to (Braunschweig & Seaman, 2014) software engineering teams must have a SU of the system design to be able to work independently but successfully integrate their code. Success also depends on the differentiated skill and experience of the team members. These issues of understanding are important to project success but are difficult to investigate with current approaches. Klimoski & Mohammed (1994) conclude that when SU is created among team members, trust is more likely to be built and performance improved. Feldman & Rafaeli (2002) similarly confirm that SU helps organizations to maintain a certain pattern of behavior, which strengthens the coordination of individuals and provides more opportunities to adapt to changes in the internal and external environment. Similarly, in (Bondarl, Katzy, & Mason, 2012) it is said that SU is one of the main contributors to organizational success; therefore, false assumptions on this issue can cause serious damage to organizations and their competitive advantage. For (Grøtan, Albrechtsen, & Skarholt, 2009) "SU has a significant impact on the ability of teams to coordinate their work and perform well" and its lack is often pointed out as one of the main causes of failure. For their part, in (Salas, Rosen, Burke, Nicholson, & Howse, 2007) discussed that there is substantial evidence that SU is vital to team performance in complex, high-stress work environments such as aviation, medicine, and the military and, therefore, should be a priority component of training systems used to prepare teams to work in these environments. For (Rosenman, et al., 2018), SU supports dynamic decision-making and adaptability in unpredictable and time-pressured situations and has been shown to improve team effectiveness in emergency response teams.

Q4.2: In what contexts is it most important to achieve shared understanding?

After analyzing the primary studies that were part of this literature review, in all contexts in which there is a collaborative activity, it is important and necessary to achieve a SU, since in order to work in a coordinated manner and with the necessary participation of all, each member must be able to understand and agree with what is going to be done within the group to achieve the objectives of the collaborative activity and also, they must understand and agree on the results obtained at the end of the activity. It was also identified in these studies that one of the contexts in which it is most necessary to achieve a SU is in problem-solving, since the process of understanding the problem, finding a solution, implementing it, and finally validating that the solution has solved the problem, requires the participation, discussion, debate, and ideas of all participants and if there is no common understanding on all these points, the success of the activity will not be fully achieved and therefore the problem will not be solved as expected. In this sense, Mulder et al. in (2002), determine that problem-based activities often go hand in hand with ill-defined problems. Group members working and learning together in problem-based projects must pay attention to a number of issues, such as the shared definition of problem statements, project objectives, division of tasks, and coordination of activities. To work and learn together, group members must have a common understanding of what they are working on, how they will work together, and with whom they will work. In other words, group members who are solving a problem need SU of the content, the task, the procedure, and the use of the technology they will use to communicate, in order to speak the same language and work toward the same goals (Mulder & Swaak, 2000).

2.5.2.3 SLR Conclusions

After performing the systematic review of the literature, the results show that, although the concept of shared understanding is a topic that has been addressed by different authors and in different contexts (health, education, collaborative work in software engineering, IT, and collaborative activities), there is a scarce number of publications where special relevance is given to the guided and detailed way in which such shared understanding can be built, and even more, they do not focus on mechanisms that allow its measurement, the moment in which it should be done and what actions to take if it is not correctly and completely built among the participants. This concept of shared understanding in most of the primary studies analyzed focuses on the overlapping of understanding and concepts, mutual knowledge, mutual beliefs and mutual assumptions, the state of group consensus, ability to coordinate behavior, and definitions that focus on the achievement of the objectives set out in the different types of collaborative activities and in the different contexts, so it can be seen that the definition does not depend on a specific context, it is basically a cognitive aspect to be achieved in a group and does not depend on the subject matter of the collaborative activity. However, in the studies analyzed, it continues to be an aspect whose construction is taken as obvious and the consequences of not achieving it are only seen when the collaborative activity is over. In addition, no indicators have been defined for its measurement that facilitates the determination of its construction or not, in the groups that seek to solve an activity. Some metrics have been used that are varied and depend on the mechanism to be used to make the respective measurement, among which are the perception of the participants, measures of shared priorities, measures taken from the dialogues generated among the participants, and measures taken from shared mental models. Similarly, in the studies analyzed, it is possible to determine the moments in which the need to achieve shared understanding is defined, in the beginning, at the end, and during the collaborative activity. Most of them focus on the fact that it should be achieved at the end of the activity, to determine that everyone has the same understanding of what has been done. On the other hand, the positive effects and benefits of building shared understanding among the members of a group were determined, according to the studies reviewed: better production performance both in quantity and quality of the products obtained, individual and group satisfaction, reduction of iterative loops, improvement in team morale, greater integration of knowledge, and as a consequence, better communication.

Chapter 3

METHOD ENGINEERING FOR THE CONSTRUCTION OF THUNDERS PROCESS

3.1 Overview

This chapter shows the process of THUNDERS building following an adaptation of the situational method engineering (SME) approach. THUNDERS is a process for improving computer-supported collaborative work through the construction, monitoring, and assisting shared understanding in problem-solving activities. Initially, the construction of the process was based on the work presented in (Collazos, Muñoz Arteaga, & Hernández, 2014), which was later updated and improved in other works, such as CSCoLAD and in a subsequent re-definition. Considering this last version, an exploratory study was conducted to identify the improvement opportunities that were not yet resolved in the collaborative work, and with them, and making use of the SME approach, the requirements that THUNDERS should support were identified, in addition to classifying and selecting the components that would be part of it, through the characterization of the environment and the comparison of the content elements of the method. Subsequently, for the assembly of the elements that would be part of THUNDERS, the elements of the method and the components and structure of the process were defined, and in this way, formalize it, using the process editor Eclipse Process Framework Composer which conforms to SPEM 2.0 (Software & Systems Process Engineering Metamodel), and with this formalized process, perform their respective validations. The sections of this chapter are summarized in the following image (See Figure 3.1).

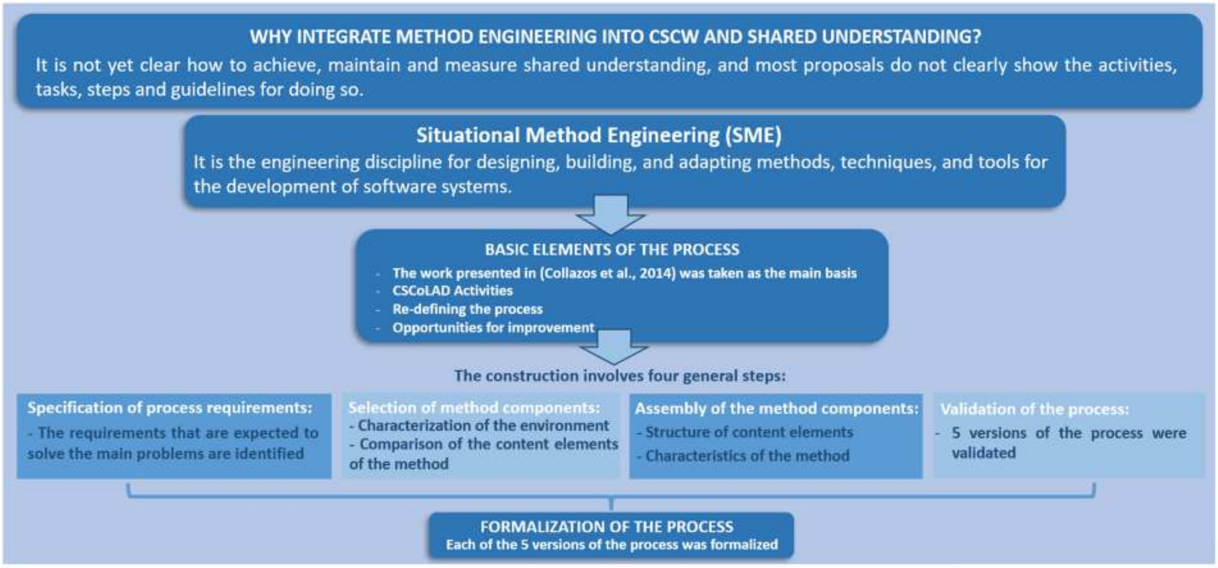


Figure 3.1 Sections presented in this chapter

3.1.1 Why integrate method engineering into CSCW and shared understanding?

Based on the related works and the systematic literature review, it can be determined that there are several proposals for the construction of shared understanding and its measurement in collaborative activities, however, it is important to emphasize that there is no "best approach", all of them have strengths and weaknesses, and it is even necessary to specify how it should be built, i.e., to define a step-by-step approach to achieve this shared understanding from the moment a collaborative activity is designed and executed, and then validate that the objective of the activity has been met so that it can be repeated and the benefits of shared understanding can be reaped. Added to this, in many of the works found and analyzed it is shown that shared understanding is given as something obvious (Varas Cortés, 2021) that must occur in every collaborative activity and few studies define indicators, metrics, and clear measures to determine its construction or not, at specific moments of the collaborative activity (Bittner & Leimeister, 2014). In addition, it is still not clear how to achieve, maintain and measure it in collaborative activities, considering the whole process of design, execution, and validation (Oppl, 2017). And those proposals analyzed, which define how to build this understanding, do not clearly show the activities to achieve it, or the guidelines are described at a high level, which makes them not easy to apply, nor to instantiate concrete steps (Jentsch, Beimborn, Jungnickl, & Renner, 2014). The low formalization is evidenced by the discrepancy of activities (Berggren, Johansson, & Baroutsi, 2017), the use of different names, and the heterogeneity of suggested artifacts (Kim & Shah, 2016). This lack of clarity generates ambiguities and doubts that do not help the participating actors to design collaborative activities thinking about achieving shared understanding, throughout the activity to generate better collaboration and therefore better results (Rosenman, et al., 2018).

Considering what was analyzed above, it was determined the need to use a method that would support the construction of a process that would solve all these needs, so it was determined to use Situational Method Engineering (SME) as a method to support the construction of the process, initially, through the identification of the needs of the context (Sobernig, 2020), in order to design and build work products (artifacts), activities, tasks, steps, with their respective description, that seek to meet these requirements and thus guide people who want to perform collaborative activities where shared understanding is built, thus generating greater collaboration with each of these artifacts and facilitating the applicability of shared understanding and obtaining all its benefits.

3.2 Situational Method Engineering (SME)

As previously stated, Situational Method Engineering (SME) is the engineering discipline for designing, building, and adapting methods, techniques, and tools for software systems development. A method can be defined as an approach to carrying out a software systems development project, based on a specific way of thinking, consisting of guidelines, rules, and heuristics, systematically structured in terms of development activities, with corresponding development, work products, and developer roles (Henderson-Seller, Ralyté, & Ågerfalk, 2014). Design and construction of methods based on method engineering are performed from method parts as a building unit that can be method fragments, method chunks, or method components (Henderson-Seller, Ralyté, & Ågerfalk, 2014) (Henderson-Seller, 2010). The construction involves three general activities: specification of method requirements, selection of method components, and assembly of the selected method components (Ralyté, 2013).

Considering this, what is built for this research is a process to improve computer-supported collaborative work. THUNDERS process, was built following the methodological support of SME, using its three general activities: specification of the process requirements, selection of the method components, and assembly of the selected components (Henderson-Seller, 2010) (Ralyté, 2013), and including a fourth activity, of validation of the proposed process.

These activities were executed following an iterative and incremental life cycle (See Figure 3.2). Each iteration corresponds to a complete cycle of the spiral, which involves a progression that addresses the same sequence of activities but generates a new version of the proposed process (considering the methodology presented in Chapter 1, 5 iterations were performed), each iteration includes a validation step performed through empirical studies, in addition to preparing the next cycle, which allows feedback between the different activities and iterations. The following sections summarize each of the activities that followed the process of building THUNDERS using SME.

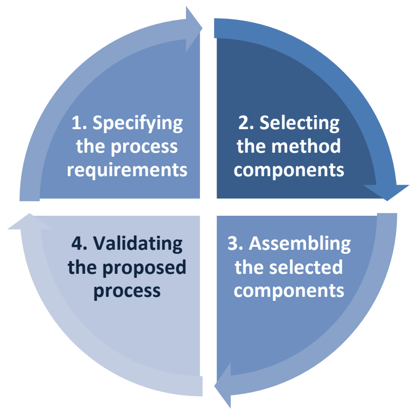


Figure 3.2 Construction of the proposed process

3.2.1 Basic elements of the process

The idea of creating a computer-supported collaborative learning process was developed by the work presented in (Collazos, Muñoz Arteaga, & Hernández, 2014) which has been the basis for other works that seek to improve collaboration and was also the main basis for the construction of the THUNDERS process. Collazos et al. (2014) defined a process for the execution of collaborative activities in the context of education; this process contained only a definition of three phases (Pre-Process, Process, and Post-Process) with their corresponding activities. The Pre-Process activities were mainly coordination activities and the definition of strategies for the structuring of the collaborative learning activity, the Process was the execution of the activity and the Post-Process activities were the main activities for the evaluation of the work and the learning obtained. The phases, Pre-process and Post-process, were to be carried out entirely by the teacher, those related to the Process phase were to be carried out, to a large extent, by the members of the group, and those activities in this phase that were coordination activities were to be carried out by the teacher. The classification of each activity according to the phase defined is presented below in Table 3.1:

Pre-Process	Process	Post-Process
Design the contents	Application of strategies	Inspect the success criteria
Specify the size of the groups		
Organize the groups	Intra-group cooperation	

Organize the room	Testing the success criteria	Present the closure of the activity
Distribute the material	Monitoring	
Design the roles	Providing assistance	
Specify the rules	Intervention in case of problems	Evaluate the quality of learning
Define the success criteria	Self-evaluation of the group	
Determine the desired behavior	Feedback	

Table 3.1 Activities with its corresponding phases

Considering and based on the previous work, a new proposal called CSCoLAD was made, presented in (Collazos C. , 2014) which modifies, adapts, and improves some activities of the previously presented process, in addition to incorporating new elements, including: roles for each activity, and input and output work products. These changes were made considering selection criteria that influence the generation of collaborative learning in students, which refer to the key characteristics of collaborative learning: Positive Interdependence, Equal Participation, and Individual Responsibility. CSCoLAD provides in this sense, a generic alternative to solve the design of collaborative learning activities of any type and educational level, following the previous structure of three phases with their respective activities, which are shown in the following Table 3.2:

Pre-Process	Process	Post-Process
Definition of the population	Briefly describe the learning activity	Review success criteria
Determine the thematic units	Formation of groups	
Define pre-conditions for students	Assign roles	
Define the objectives	Distribution of materials	
Review the strategies or techniques according to the type of activity	Initiation of the activity	
Designing the tasks	Maintain collaborative momentum	
Define success criteria	Test the success criteria	Conduct a summative evaluation
Specify the rules of the activity	Conduct a formative assessment	
Decide on the grouping of the students	Provide feedback	
Design the roles	Present the closure of the activity	
Select and/or design of materials	Groups compare their results with each other	
Designing the evaluation		

Table 3.2 CSCoLAD Activities

Considering these works and analyzing the results obtained after its application, a new adaptation of the phases, activities, and work products was made, incorporating tasks, steps, monitoring, and evaluation elements for each task, work presented in (Agredo-Delgado, Ruiz, Collazos, & Fardoun, 2019). Thus, defining a more detailed process with more support for its application, which continued to be defined for the same educational context, solving many of the needs previously encountered, and with the same three-phase structure. Each of the activities in each phase are shown in Table 3.3 below.

Pre-Process	Process	Post-Process
Definition of the population	Describe the activity	Review success criteria
Determine thematic units	Formation of groups	
Define pre-conditions of the students	Assign roles	
Define the objectives	Distribute materials	
Design the tasks	Initiate the activity	
Define success criteria	Test the success criteria	Conduct a summative evaluation
Specify the rules of the activity	Conduct a formative evaluation	
Decide on the grouping of the students		
Design the roles	Closing the activity	Feedback
Select and/or design of materials	Sharing results	
Design the evaluation		

Table 3.3 New definition of activities for each phase

According to this last research work focused on the improvement of collaboration, and analyzing the results obtained after its application, this work is taken as the basis for the construction of THUNDERS following SME. For this it was first necessary to identify the requirements of the new method to be built, and to look for new gaps or deficiencies, for which a new exploratory case study was conducted, applying this latest version of the collaborative learning process (work is presented in (Agredo-Delgado, Ruiz, Collazos, & Fardoun, 2019)), continuing with the context of education. Where it was validated if the phases and each of its elements were useful and allowed learning and collaboration. For the case study, a software tool called GamiMoodle (Tool designed for the study) was used, which supported the application of each of the steps of the process, from its Pre-Process phase to its Post-Process phase. For this study, students were organized into groups of 5 students organized by the teacher, and each group collaboratively was responsible for carrying out a module of a class project where they had to build a software product that would be responsible for systematizing the processes and information that is handled in the gyms of the Universidad del Cauca. At the end of the activity, each participant had to fill out surveys to validate the applied process.

After the application of this process, with the results obtained and the observation made throughout the execution of the study, a set of opportunities for improvement were identified, in order to determine those existing needs that have not yet been solved and that seeks to improve collaboration in group activities. These opportunities for improvement can be seen in Table 3.4 below.

Deficiency	Justification	Opportunity for improvement
The teacher does not know how to form the groups	In order to design activities according to the characteristics of the students (Barron, 2003), the teacher must carry out a prior analysis of	Provide a series of mechanisms that allow the teacher, before executing the activity, to know the participants in

	the different characteristics of these students (Razmerita & Brun, 2011) (Moşteanu, 2021).	order to form groups with appropriate characteristics for better collaboration and thus focus the entire design of the activity.
Lack of steps to design a collaborative activity of specific types	When the teacher wants to design a collaborative activity and has a detailed step-by-step, the activities will be suitable for the groups and the desired topic (Bittner & Leimeister, 2014) (Rupert & Pehrson, 2019).	Provide the teacher with a simple and explained guide for the detailed design of a collaborative activity that meets the requirements of the group, the topic and the specific type of activity to be designed.
The teacher executes the entire collaborative process	By having a defined process, it is necessary to have roles that can be assumed by different people, in order to take advantage of the necessary experience or knowledge of each one, for the design or execution of specific tasks (López Trujillo & André Ampuero, 2006).	Provide within the process a set of specific and detailed roles and responsibilities to carry out the activities and tasks of the process.
The teacher does not know how to design roles according to the needs of the collaborative activity	When planning a collaborative activity, the responsibilities that students should play within the groups should be considered in order to maximize collaboration and obtain better results (Durán, Calo, & Argañaraz, 2012) (Naseebah, Mohsen, & Bechkoum, 2019).	Provide the teacher with a mechanism that facilitates the design of roles and responsibilities according to the activity and the characteristics of the students, in order to monitor these assignments.
The teacher does not have a guide or support to design the validation mechanisms	Before starting the activity, it is important to define the criteria and the way in which the different aspects of performance will be validated (Izquierdo Alonso & Iborra Cuellar, 2010) and the fulfillment of the objective of the activity (Kasse, Xu, deVrieze, & Bai, 2018).	Provide the teacher with detailed and guided support for the design of the validation mechanisms for the different aspects needed to be evaluated in the collaborative activity.
There is no monitoring of process activities	It is necessary to monitor each activity, task, and step that is defined within the collaborative process to ensure compliance with what was previously designed and established (Frankel & Gage, 2009) (Strauß & Rummel, 2020).	Provide the teacher with a mechanism to monitor each flow of the process and ensure complete and correct fulfillment of each activity and task designed.
The teacher does not know how to design activities to foster collaboration	It is important not only to create a collaborative activity by defining its elements, but it is necessary that these have the purpose of fostering collaboration with each of its aspects (Child & Shaw, 2016) (Echeverria, Martinez-Maldonado, & Buckingham Shum, 2019).	Provide the teacher with mechanisms that support the design of activities that really encourage collaboration and, in this way, achieve the correct fulfillment of the objective of the collaborative activity within the group.
There are participants who do not collaborate in the development of the activity	Generating collaborative participation among the members of a group is not a simple task (Kim & Shah, 2016), it is not only important to consider technological aspects and the design of the activity, but it is also necessary to analyze the cognitive aspects of the participants (DeFranco, Neill, & Clariana, 2011) (Gašević, Joksimović, Eagan, & Shaffer, 2019).	When designing the activity, defining roles, creating groups, and other elements of a collaborative activity, it is necessary to consider how cognitive aspects can be generated to enable greater collaboration. Therefore, it is necessary to provide this information clearly and support its definition, giving the teacher a guide to building such aspects.

Table 3.4 Opportunities for improvement identified

From the analysis of these identified opportunities for improvement, and according to the literature review previously shown, it was determined that it is necessary to define a process that guides through a step by step, the design of collaborative activity with each of its elements, the support of its execution and finally that guides the evaluation of the performance of the participants and the fulfillment of the objectives. In addition, according to all the information collected, it was determined the need to consider a cognitive aspect that improves collaboration (Christiane Bittner & Leimeister, 2013), therefore, after analyzing the benefits that can be obtained by achieving a shared understanding, it was determined to include this aspect in the definition of the process (Van den Bossche, Gijselaers, Segers, Woltjer, & Kirschner, 2011). It was also specified that the type of collaborative activities that most need to improve communication through shared understanding are collaborative problem-solving activities (Langan-Fox, Anglim, & Wilson, 2004), considering this type of activities to define a process to improve collaborative work through the construction, assistance, and monitoring of shared understanding.

3.2.2 Specification of process requirements

As previously mentioned, SME was used to guide the construction of THUNDERS (According to SME, the process will be the method to be defined), for this, the first activity was executed, which refers to the specification of the requirements of the method, which were the guideline for the construction of the proposed process. In other words, the necessary conditions were identified that the method would have and therefore, these conditions should solve the problems and deficiencies, which were identified from the information previously collected, the opportunities for improvement, the literature review, and the related works analyzed. Table 3.5 shows the requirements or needs (rows of the Table), which would solve the main problems or deficiencies (columns of the Table):

Process requirements	Collaboration is difficult to build	Ineffective participation	Few guidelines in collaboration for problem-solving	How and when intervene in collaborative work	Lack of conceptual clarity in shared understanding	What drives the construction of a shared understanding?	Inadequate technological support
It must include the elements involved in collaborative work	x	x	x	x			
It must support each of the phases of collaborative work	x	x		x			
It must allow building collaboration	x	x	x	x		x	
It must allow the construction and measuring of shared understanding					x	x	
It must provide monitoring and assistance				x			x
It must support the formation of heterogeneous groups		x	x				
It must support the design of the collaborative activity	x		x	x	x	x	
It must be evolvable and maintainable	x	x	x	x	x	x	x
It must have a formal description	x					x	x
It must allow easy access	x						x

to its definition							
It must provide reusable components	x					x	x

Table 3.5 The requirements vs. the main problems or deficiencies identified

3.2.3 Selection of method components

The second SME activity is to select the components of the method, where the objective was to classify and select the possible components that would be part of the proposed method. To carry out this activity, the tasks of characterization of the environment and comparison of the content elements of the method were performed, tasks that are detailed below.

3.2.3.1 Characterization of the environment

The purpose of the task, characterization of the environment, was to identify general aspects, characteristics, and content elements of the method that have been previously used, researched, or analyzed by those who have designed, executed, and validated collaborative activities, regardless of the context used. In addition to structuring the elements that would be incorporated into the definition of THUNDERS from the perspective of theory and practice in a real application environment.

For this purpose, the process applied in the exploratory case study shown above and the improvement opportunities obtained as a result of this study were taken as a basis (Information presented in section 3.2.1 Basic elements of the process, of this chapter), where it was also possible to identify the elements and practices used, in this case, by both teachers and group participants (It should be clarified that THUNDERS is not focused solely on the educational context and that this exploratory study served to analyze the first elements that would form it and with the subsequent validations, where it was applied in different contexts, new elements were incorporated, according to the needs that were identified). In addition, another source of information for this characterization was found in the systematic review of the literature and each of the reviews on the topics addressed in this project (information shown in Chapter 2).

As a result of the analysis of these previous sources of information, the following aspects, and characteristics to consider for the construction of THUNDERS were identified:

- Definition of collaborative problem-solving activities
- Formation of heterogeneous groups
- Process-based on the construction and measurement of shared understanding

- Definition of roles both for both the application of the process and the execution of the collaborative activity
- Structuring of the process elements into an activity design phase, an activity execution phase, and a validation and evaluation phase
- Process monitored and assisted in each of its phases
- Each phase should be guided by activities, tasks, and steps
- Each task must have a variability, where it is defined whether each task must be executed compulsorily, and which ones are executed depending on the context
- In structuring the content elements of the method, the use of the following work products were identified as common: diagram of the process, design of the collaborative activity, characterization of the groups, design of evaluations, formats of execution of the activity, description of the activity, assignment of groups, roles and material, results obtained from the activity, self-evaluation of the participants, feedback for the participants

3.2.3.2 Comparison of the content elements of the method

The purpose of this task was to identify the common base elements that would form part of the THUNDERS process by comparing elements obtained from the following sources of information:

- The base processes were considered (the process carried out in (Collazos, Muñoz Arteaga, & Hernández, 2014) – called Version 1, CSCoLAD presented in (Collazos C. , 2014) – called Version 2 and finally its evolution that was applied in the exploratory study – called Version 3)
- Interviews with the participants of the exploratory study (teacher, students)
- Interviews with experts in collaboration. Expert 1 (E1), Expert 2 (E2)
- Related works (those that could be most relevant to the process were selected)
- Primary works from the systematic literature review (those that could contribute elements to the process were selected)

To identify these common elements, initially, **¡Error! No se encuentra el origen de la referencia.** shows the common characteristics to be considered for the construction of THUNDERS identified from the information sources.

	Basis processes					**Collaborative Experts**		**Paper number (Primary papers)**						**Related works**							
Process characteristics	**Version 1**	**Version 2**	**Version 3**	**Teacher**	**Students**	**E1**	**E2**	**1**	**3**	**5**	**12**	**20**	**21**	**(De Haan, 2001)**	**(Bittner & Leimeister, 2014)**	(Aubé, Rousseau, Brunelle, & Marques, 2018)	**(Nakakawa, Van Bommel, Proper , & Mulder, 2018)**	**(Mulder & Swaak, 2002)**	**(Bates, et al., 2014)**	**(Braunschweig & Seaman, 2014)**	**(Cash, Dekoninck, & Ahmed-Kristensen , 2017)**
Collaborative problem-solving activities				X	X	X	X	X	X	X	X	X	X					X	X		X
Formation of heterogeneous groups				X	X	X			X	X			X		X		X		X	X	
Construction of shared understanding						X	X	X	X	X	X	X	X		X		X	X		X	X
Measurement of shared understanding						X	X	X	X	X	X	X	X		X			X	X	X	X
Roles for the process application	X	X	X			X	X								X						
Roles for the execution of the collaborative activity	X	X	X	X	X	X	X		X	X		X		X		X		X		X	
Process defined in phases	X	X	X	X		X			X						X		X				X
Process monitored and assisted			X	X		X							X					X			
Definition of activities, tasks, and steps		X	X	X			X							X	X	X		X	X		
Variability of process elements																					
Assisted process with templates, guides, and documents					X	X					X		X			X					

Table 3.6 Common characteristics of the method

Table 3.7 shows the work products identified and commonly used by the same information sources used above. It is important to clarify that, although the names of the work products in some information sources were not the same, the relationship was made with respect to their objective, content and/or use, thus determining that they were common in the respective information source.

	Basis processes					**Collaborative Experts**		**Paper number (Primary papers)**						**Related works**							
Process Work Products	**Version 1**	**Version 2**	**Version 3**	**Teacher**	**Students**	**E1**	**E2**	**1**	**3**	**5**	**12**	**20**	**21**	**(De Haan, 2001)**	**(Bittner & Leimeister, 2014)**	(Aubé, Rousseau, Brunelle, & Marques, 2018)	**(Nakakawa , Van Bommel, Proper , & Mulder, 2018)**	**(Mulder & Swaak, 2002)**	**(Bates, et al., 2014)**	**(Braunschweig & Seaman, 2014)**	**(Cash, Dekoninck, & Ahmed-Kristensen, 2017)**
Process diagram		X	X	X	X	X	X		X						X						
Collaborative activity design	X	X	X	X		X	X	X	X	X	X	X	X					X	X		X
Characterization of the groups						X	X		X	X			X					X	X		X
Design of evaluations		X	X	X		X	X				X			X		X				X	
Execution formats of the collaborative activity			X	X		X	X	X			X		X		X			X	X		X
Description of the collaborative activity	X	X	X	X	X	X	X		X	X	X	X			X			X	X		X
Assignment of the groups	X	X	X	X		X	X	X	X		X		X	X				X	X		X
Assignment of the roles	X	X	X	X		X	X		X	X		X		X		X		X		X	
Assignment of the material		X	X	X		X	X				X		X		X		X			X	X
Results obtained from the activity	X	X	X	X	X	X	X	X	X		X	X		X				X	X		X
Self-appraisal of the participants					X	X				X	X	X	X		X	X			X		X
Feedback for the participants		X	X	X	X	X	X		X			X			X	X	X			X	

Table 3.7 Common work products of the method

¡Error! No se encuentra el origen de la referencia. and Table 3.7 allowed a comparison of the elements of method content from the sources of information to choose the components, artifacts, and characteristics of the method, which were the basis for structuring the components of the method that would form part of THUNDERS.

3.2.4 Assembly of the method components

The third SME activity is the assembly of method components, which made it possible to define the structure that the previously identified content elements and characteristics of the method would have. For this purpose, the definition of three phases was used as an assembly element (*Beginning phase*, where the necessary elements for the collaborative activity are designed, planned, and constructed; *Development phase*, where the collaborative activity is executed, applying what was previously designed, in addition to validating the construction of the shared understanding; and finally, the *Measuring phase*, where the performance of the participants is evaluated, the solution to the problem is validated and the necessary feedback is provided). Each phase contains the definition of activities (with a name, a description, and an identifier), and each activity is made up of tasks (with a name, an identifier, a description, and work products such as inputs, outputs, and support documents, roles in charge of executing it, respective steps and variability options, where it is determined whether or not the task is part of the process to be executed, and information is also provided to support the inclusion or not of said task).

Figure 3.3 summarizes the elements contained in each phase, where each one may have a set of activities and each activity may consist of a set of tasks.

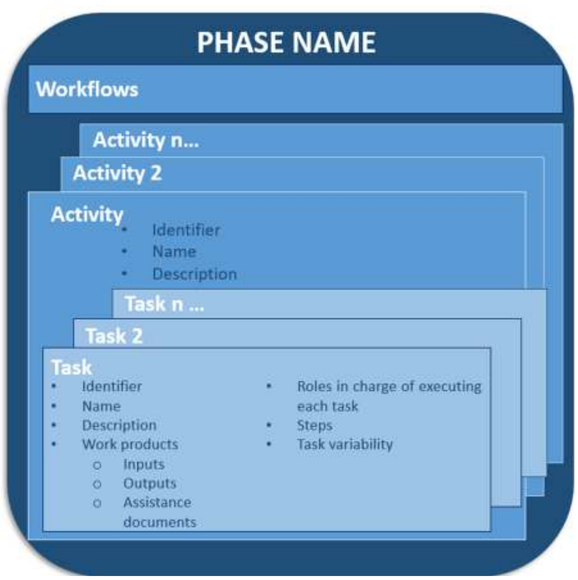


Figure 3.3 Content of each phase

According to the characteristics of the method, the following were defined: the main context of the application refers to collaborative problem-solving activities, formation of heterogeneous groups, inclusion of roles to execute the tasks of the process, and roles to execute the collaborative activity, monitoring of each of the tasks of the process, assistance in the execution of the process (which is given by two ways to execute the main tasks, one where the executor is given the "freedom" to perform the corresponding tasks, providing a set of recommendations and the second where specific templates to follow to execute the task are offered). From the point of view of validation of shared understanding, it was determined the need to be done in two moments, one to validate that all participants have understood the problem, and the objectives of the collaborative activity, and the second moment, at the end of the activity, when the problem is considered solved, in order to validate if all participants understood and agree with what was done as a solution. To evaluate the performance of the participants, an individual and group evaluation was determined. And finally, the realization of a validation of the resolution of the problem. The purpose of these validations and the evaluation is to provide feedback to the participants on the results obtained.

Identifier	Activity	Roles	Identifier	Tasks	Inputs	Type	Outputs	Type	Work products	Type
0 1	Define the population	Instrument designer	0 1 - 0 1	Design the instruments to characterize the population	Instruments design plan to characterize the population	Template	Instruments design plan to characterize the population (Filled out)	Template	Recommendations for designing the instruments	Template
									Instrument - Personality traits	Guidelines
									Instrument - Personality traits - by William Marston	Guidelines
							Instruments to characterize the population	Template	Instrument - Learning styles	Guidelines
		Activity coordinator							Instrument - Personal information	Guidelines
									Instrument - Intellectual skills	Guidelines
		Instrument designer	0 1 - 0 2	Plan the population characterization	All participants list	Template	Information gathering plan (Filled out)	Template	--	--
					Instruments design plan to characterize the population (Filled out)	Template				
					Information gathering plan	Template				
		Information collector	0 1 - 0 3	Characterize the population that will participate in the activity	Instruments design plan to characterize the population (Filled out)	Template	List of the values of the characteristic analyzed in the participants (Filled out)	Template	--	--
					Instruments to characterize the population	Template				
					All participants list	Template				
		Participants			Information gathering plan (Filled out)	Template				

					List of the values of the characteristic analyzed in the participants	Template					
		Activity coordinator	0 1 - 0 4	Analyze the information obtained in the characterization	List of the values of the characteristics analyzed in the participants (Filled out)	Template	Results of the analysis of the information obtained in the characterization (Filled out)	Template	Recommendations for analyzing the information obtained in the characterization	Template	Optio
		Information collector									
		Activity leader			Results of the analysis of the information obtained in the characterization	Template					
		Activity coordinator	0 1 - 0 5	Monitor the tasks to define the population	Monitoring the task of designing the instruments to characterize the population	CheckList	Monitoring the task of designing the instruments to characterize the population (Filled out)	CheckList	--	--	Optio
		Activity leader			Monitoring the task of planning the population characterization	CheckList	Monitoring the task of planning the population characterization (Filled out)	CheckList			
		Information collector			Monitoring the task of characterizing the population that will participate in the activity	CheckList	Monitoring the task of characterizing the population that will participate in the activity (Filled out)	CheckList			
					Monitoring the task of analyzing the information obtained in the characterization	CheckList	Monitoring the task of analyzing the information obtained in the characterization (Filled out)	CheckList			

Table 3.8 shows an example of the structure of one of the activities of the Beginning phase, called "Define the population", as an assembly mechanism, where the tasks "Design the instruments to characterize the population", "Plan the population characterization", "Know the population that will participate in the activity", "Analyze the information obtained in the characterization", and "Monitor the tasks to define the population" are linked. Each task has the elements that were previously defined, an identifier, roles in charge of executing it, in addition to a set of work products that can be inputs, outputs, or assistance documents, and that can be of different types (Templates, Guidelines, Checklist), and the variability of each task, with the respective cases for when an optional task must be executed. A color code will be used for each phase, *yellow* for the *Beginning* phase, *green* for the *Developing* phase and *red* for the *Measuring* phase. Similarly, the structure of the rest of the tasks, activities, and phases was defined (information that can be seen in *Annex 2*).

Identifier	Activity	Roles	Identifier	Tasks	Inputs	Type	Outputs	Type	Work products	Type	Variability	Observations
0 1	Define the population	Instrument designer	0 1 - 0 1	Design the instruments to characterize the population	Instruments design plan to characterize the population	Template	Instruments design plan to characterize the population (Filled out)	Template	Recommendations for designing the instruments	Template	Optional	It should be executed when group participants are unknown and there is no information on group formation characteristics
									Instrument - Personality traits	Guidelines		
									Instrument - Personality traits - by William Marston	Guidelines		
							Instruments to characterize the population	Template	Instrument - Learning styles	Guidelines		
		Activity coordinator							Instrument - Personal information	Guidelines		
									Instrument - Intellectual skills	Guidelines		
		Instrument designer	0 1 - 0 2	Plan the population characterization	All participants list	Template	Information gathering plan (Filled out)	Template	--	--	Optional	It should be executed when the "Design the instruments to characterize the population" task is executed
					Instruments design plan to characterize the population (Filled out)	Template						
					Information gathering plan	Template						
		Information collector	0 1 - 0 3	Characterize the population that will participate in the activity	Instruments design plan to characterize the population (Filled out)	Template	List of the values of the characteristic analyzed in the participants (Filled out)	Template	--	--	Optional	It should be executed when the "Plan the population characterization" task is executed
					Instruments to characterize the population	Template						
					All participants list	Template						
		Participants			Information gathering plan (Filled out)	Template						
					List of the values of the characteristic analyzed in the participants	Template						
		Activity coordinator	0 1 - 0 4	Analyze the information obtained in the characterization	List of the values of the characteristics analyzed in the participants (Filled out)	Template	Results of the analysis of the information obtained in the characterization (Filled out)	Template	Recommendations for analyzing the information obtained in the characterization	Template	Optional	It should be executed when the "Characterize the population that will participate in the activity" task is executed
		Information collector										
		Activity leader			Results of the analysis of the information obtained in the characterization	Template						

		Activity coordinator	0 1 - 0 5	Monitor the tasks to define the population	Monitoring the task of designing the instruments to characterize the population	CheckList	Monitoring the task of designing the instruments to characterize the population (Filled out)	CheckList	--	--	Optional	It should be executed when any of the tasks "Design the instruments to characterize the population", "Plan the population characterization", "Characterize the population that will participate in the activity" or "Analyze the information obtained in the characterization" is executed
		Activity leader			Monitoring the task of planning the population characterization	CheckList	Monitoring the task of planning the population characterization (Filled out)	CheckList				
		Information collector			Monitoring the task of characterizing the population that will participate in the activity	CheckList	Monitoring the task of characterizing the population that will participate in the activity (Filled out)	CheckList				
					Monitoring the task of analyzing the information obtained in the characterization	CheckList	Monitoring the task of analyzing the information obtained in the characterization (Filled out)	CheckList				

Table 3.8 Structure of the activity "Define the population"

3.2.5 Validation of the process

The fourth SME activity is the validation of the process, as previously mentioned, five iterations of each SME cycle were carried out with each of the activities previously shown. Specifically, the following shows each of the iterations of this activity, where each version of the process was validated, which was built iteratively and incrementally, considering each of the opportunities for improvement, the requirements identified, and the elements that were included for each iteration until a final version was obtained.

Figure 3.4, shows in summary what was done in the validation of each iteration and on the right the results obtained in each one.

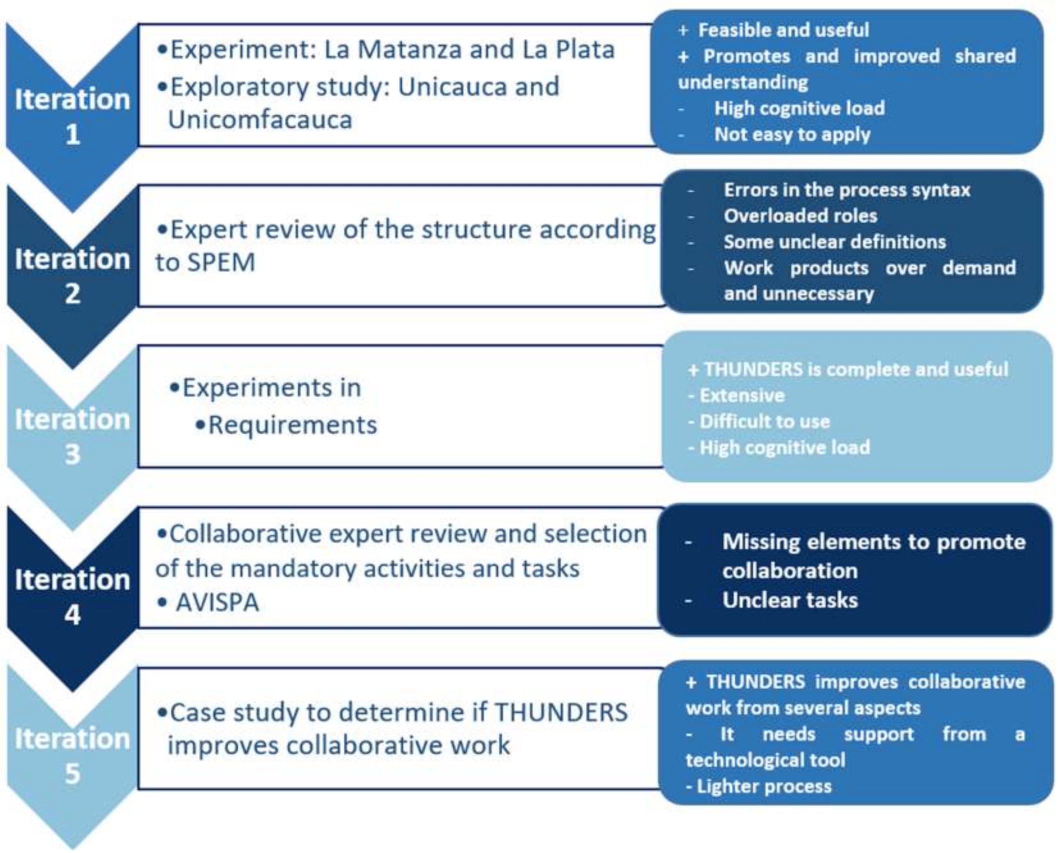


Figure 3.4 Summary of validation and results in each iteration

- *First iteration*: A version of the process was defined where collaborative work, the construction and measurement of shared understanding, problem-solving activities, and the formation of heterogeneous groups were considered. This version had the specification of 2 phases, the Pre-Process, and the Process. This version was validated through an experiment and an exploratory study, with a group that used the process and a control group that did not use it, in the experiment the feasibility and usefulness of the process was validated, and in the exploratory study, whether this version of the process promoted and improved shared understanding. As a result, it was obtained that this version was feasible and useful, however, its application generated a high cognitive load and was not easy to apply, it was also obtained that it was a process that promoted and improved shared understanding in those groups that applied the process.

- *Second iteration*: Considering the results obtained in the validation of iteration 1, new elements were included: among them new monitoring and assistance mechanisms (the aim was to support the construction of the shared understanding, the formation of heterogeneous groups, the design of the collaborative activity, the validation of the shared understanding, the evaluation of the participants' performance and the validation of the fulfillment of the problem), the Post-Process phase was defined and specified. This new version was validated by experts in software and process engineering, who validated the syntax and semantics of the process, in such a way that some errors were identified in the process specification made in SPEM 2.0 (OMG, 2007).
- *Third iteration*: The errors found by the experts were corrected, and a new version of the process was created, seeking to reduce the cognitive load in its use. This version was called THUNDERS, with which an experiment was conducted to validate if it is complete, useful, and easy to use in the construction of shared understanding in a requirements engineering context. With this experiment, it could be determined that THUNDERS is complete and useful. However, it is still a long process, difficult to use and, when used, generates a high cognitive load.
- *Fourth iteration*: Considering the results of the previous validation of THUNDERS, some definitions and relationships of inputs and outputs, and work products, were improved, generating a new version. This new version was subjected to validation by experts in collaboration issues, in order to select the tasks that are or are not mandatory in the execution of the process. As a result, some missing elements were found to promote collaboration and unclear tasks, in addition, a validation of the process was performed with AVISPA-Method (Camacho, Hurtado-Alegria, & Ruiz-Melenje, 2016) to perform a visual analysis of the process model.
- *Fifth iteration*: With the results from the experts, corrections and updates were made, generating a new version. This version was validated in a case study to determine if the application of THUNDERS in a problem-solving activity improved collaborative work. As a result, the use of THUNDERS does improve considerably the collaborative work from several aspects such as collaboration, better results obtained, and better satisfaction on the part of the participants, however, it still needs a technological support that allows it to help in the complete execution, and even to be easier and lighter to use.

The details of each validation can be found in Chapter 5.

3.3 Formalization of the process

The formalization of the process (each of the process versions) was performed using the Eclipse Process Framework (EPFC) which is in accordance with the SPEM 2.0 metamodel (Software Process Engineering Meta-Model) (OMG, 2007). The formalization of the process was carried out so that THUNDERS has a defined and formalized model through a formal language that will provide possibilities for a better management of the content elements, in addition to providing mechanisms for adaptation, dissemination and evolution. According to the SPEM 2.0 process creation framework, the formalization of THUNDERS started with the definition of the content elements previously identified in the environment characterization activities and the comparison of the content elements. The assembly of the content elements was materialized through the formalization of the relationships between these elements, obtained the following formalized process (See Figure 3.5).

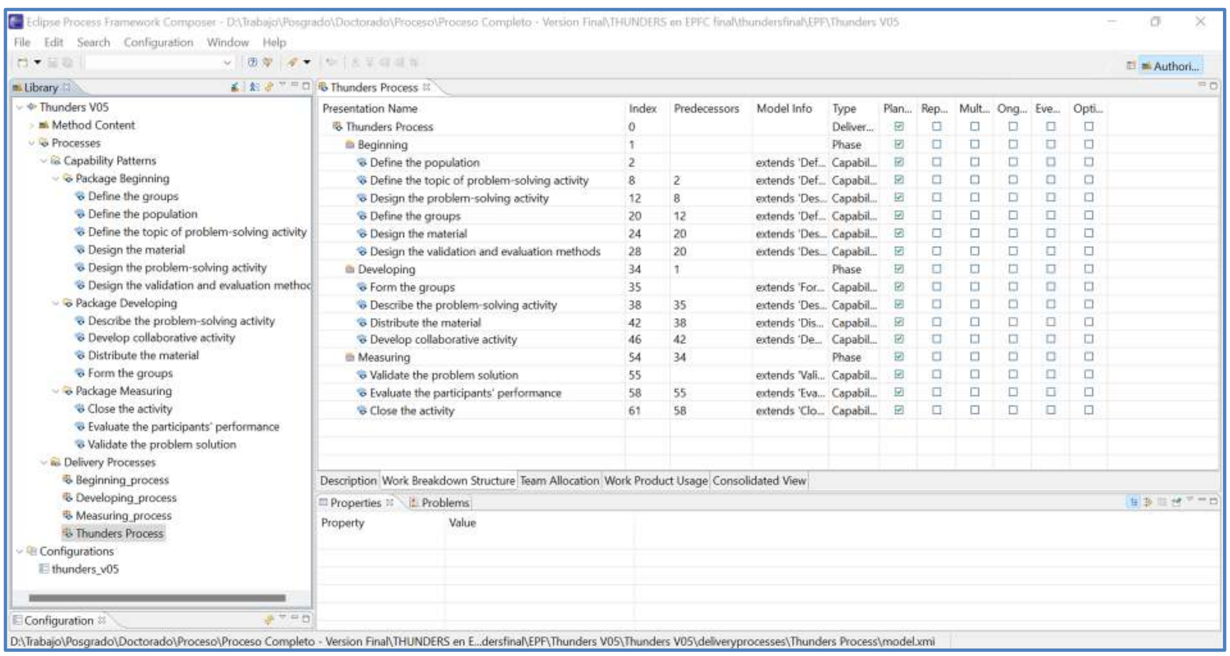


Figure 3.5 THUNDERS specified in EPFC

Chapter 4

A COLLABORATIVE WORK PROCESS BASED ON SHARED UNDERSTANDING: THUNDERS

4.1 Overview

This chapter shows the structure, elements, and philosophy, which is defined by the characteristics, pillars, and principles behind the solution idea defined in THUNDERS, being a process that seeks to improve collaborative work through the construction, monitoring, and assistance of shared understanding in problem-solving activities. This process is an approach to design, execute and validate a collaborative activity supported by the formation of heterogeneous groups, monitoring, and assistance of the whole process. The process consists of three specific phases, each of which contains activities, tasks, steps, and work products (inputs, outputs, and assistance documents), with corresponding roles, all of which are framed in workflows. In addition, the chapter shows how the defined process supports each of the requirements that were previously identified during its construction. It also shows and details the structure and each of the elements of the Beginning phase, and the other phases are detailed in the *Annex 3*. The sections of this chapter are summarized in the following image Figure 4.1**¡Error! No se encuentra el origen de la referencia.**.

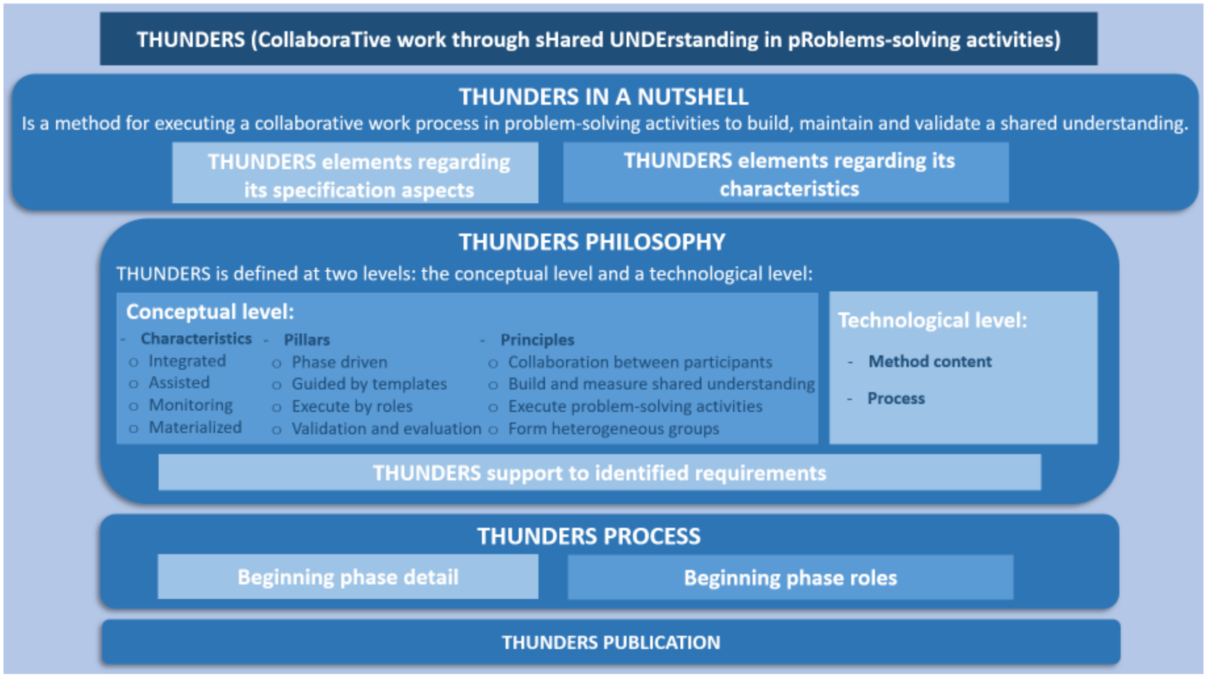


Figure 4.1 Sections presented in this chapter

4.2 THUNDERS in a nutshell

THUNDERS (CollaboraTive work through sHared UNDErstanding in pRoblems-solving activities) is a method to execute a collaborative work process in problem-solving activities, which contains elements that allow to build, maintain and validate a tangible shared understanding, described and composed from a defined and structured specification of artifacts so that with its construction the communication of heterogeneously formed groups of participants improves and as a consequence of better communication and coordination, the collaboration during the achievement of the solution to the problem posed is improved. THUNDERS aims to guide the actors involved in the entire collaborative process by describing systematic steps, from the design of an activity that promotes shared understanding and each of the elements necessary for its execution, in the same way, it aims to guide the execution of the activity among the participants of the groups, validate the shared understanding and finally guide the validation of the solution to the problem, and the evaluation of the performance of the participants, providing the necessary feedback. In addition to providing a set of monitoring and assistance elements that allow the design of a collaborative activity that fosters and encourages collaboration and shared understanding among the different roles involved during its preparation.

4.2.1 THUNDERS elements regarding its specification aspects

THUNDERS contains a number of elements defined from different aspects. Initially, from the process specification aspects, it contains the following elements.

- *Process*: In the context of this research, the definition of process is used which determines that: is a sequence of steps arranged with some kind of logic that focuses on achieving some specific result (Humphrey, 1989). In this sense, THUNDERS is a process (defined at two levels: the conceptual level that defines how to execute a collaborative activity through strategies, activities, tasks, rules, steps, roles, inputs, results, and a technological level that provides the technical support to achieve it and allows the process to be easily reusable) that allows the design, execution, and validation of a collaborative activity, which determines a sequence to guide the needs of collaborative work in a systematic way.
- *Process roles*: It defines who is in charge and responsible for executing a specific task. Roles are a set of related skills, competencies, and responsibilities of an individual or a group. It may happen that an individual plays several roles or that a role is played by several individuals.
- *Phases*: THUNDERS defines 3 phases, which refer to a significant period of the process and end with a major management control point, milestone, or set of completed results.
- *Activities*: Each THUNDERS phase contains a set of defined activities, representing an overall unit of work.
- *Tasks and steps*: Each THUNDERS activity contains a set of tasks and each task a set of steps that are the basic, atomic building blocks of the process, representing the effort to be performed. Tasks affect some work products and link roles for their execution.
- *Workflows*: THUNDERS contains a set of workflows that are the operational aspects of an activity and show the flow of each of them.
- *Work products*: THUNDERS tasks consume, produce, or modify work products, which can be of type Artifact: of tangible nature (model, document, code, files...). Deliverable: provides a description and definition to package other work products for delivery. Outcome: of an intangible nature (result or state), or that is not formally defined.
- *Guidelines*: A process element that guides in detail the execution of some aspects of THUNDERS.

4.2.2 THUNDERS elements regarding its characteristics

THUNDERS is also made up of specific characteristics that allow it to achieve its objective when applied, which is why, from the point of view of process characteristics, it contains the following elements, which can be seen in Figure 4.2.

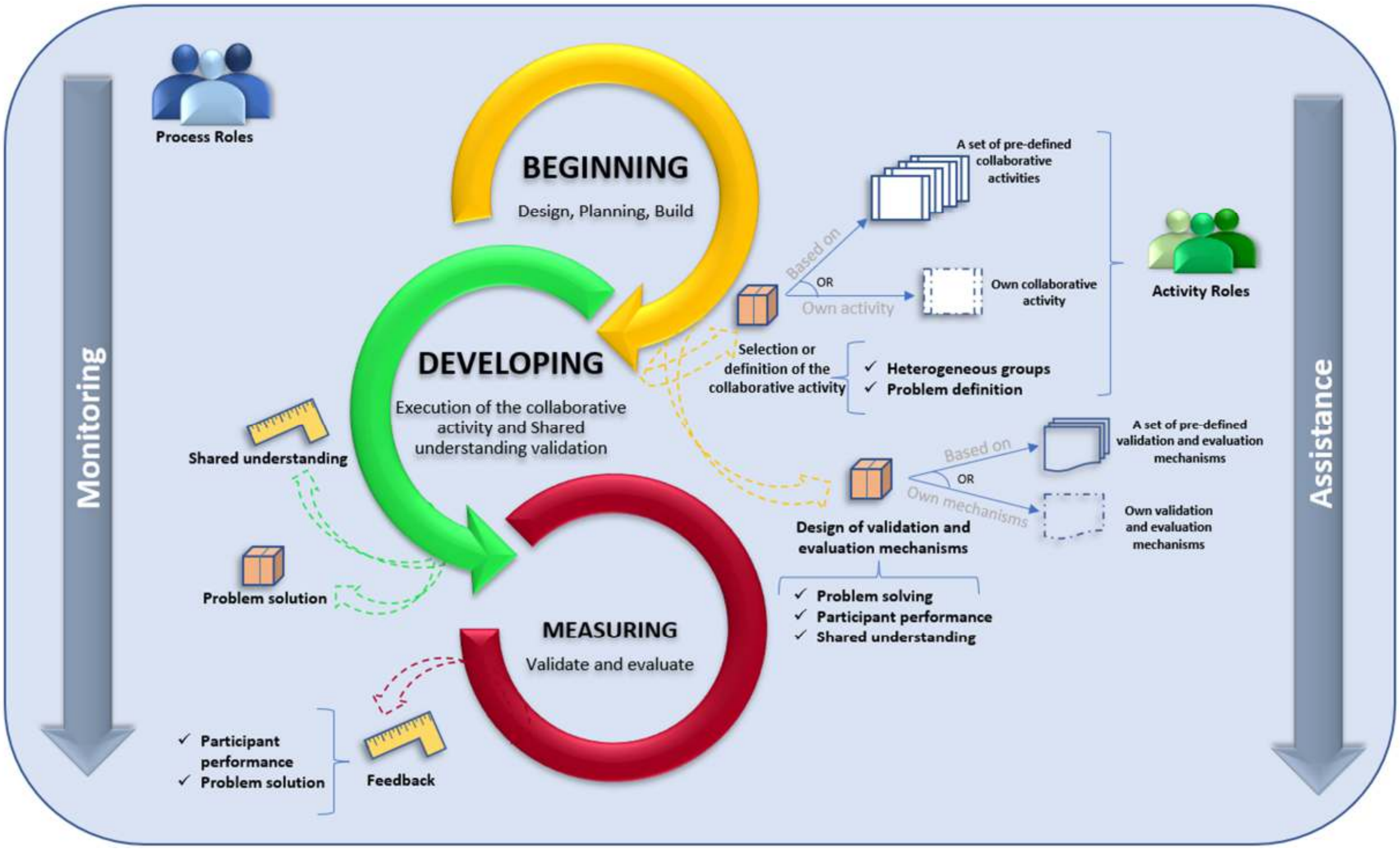


Figure 4.2 THUNDERS elements regarding its characteristics

- Phases:
  - Beginning phase: In this first phase, the collaborative activity and each of its elements are designed, planned, and constructed, as well as the coordination, monitoring activities, and the different strategies necessary to apply in the subsequent execution of the collaborative activity and to meet the previously planned objectives. Activities are defined: *Define the population*, *Define the topic of problem-solving activity*, *Design the problem-solving activity*, *Define the groups*, *Design the material*, and *Design the validation and evaluation methods*.

    The milestone of this phase is:
    - Selection or definition of the collaborative activity: The role in charge of the design, previously selects the way to design the collaborative activity with each of its elements, either by choosing one of the six collaborative activities provided or according to its autonomy, but considering the recommendations given by the process. The design of the roles with their respective responsibilities is also obtained, which can be designed either by choosing those recommended by THUNDERS or by designing them according to the designer's criteria under the recommendations given.
    - Design of validation and evaluation mechanisms: The role in charge of the design previously selects the way to design the validation mechanisms of the shared understanding construction, and of the problem fulfillment. In addition to the design of the mechanisms for evaluating the performance of the participants, either by choosing some of the mechanisms and strategies provided in the process or by carrying out the design following the given recommendations.
  - Developing phase: In this phase, the collaborative activity designed in the previous phase is executed to achieve the previously planned objectives and solve the proposed problem through the interaction among the group members, generating the construction of the shared understanding and validating, in the two moments indicated, its construction. In this phase all the activities planned in the Beginning phase are carried out, controlling their complete and correct execution. In addition to being able to provide the required assistance when necessary, intervening in the groups and carrying out different strategies to achieve what was previously planned. Activities are defined: *Form the groups*, *Describe the problem-solving activity*, *Distribute the material*, and *Develop collaborative activity*.

    The milestone of this phase is:
    - Shared understanding measurement: According to what was designed and planned in the previous phase, measurements (according to the mechanisms and strategy chosen) of shared understanding are performed in two stages,

one, after understanding the description of the collaborative activity with the respective objectives, and the second, at the end of the problem-solving.

- Problem-solution: Participants generate a solution to the problem posed in the collaborative activity.

- Measuring phase: At the end of the collaborative activity, the activity coordinator (the person in charge of guiding the activity) carries out an individual and collective evaluation to determine the achievement of the different proposed objectives, the achievement of the problem resolution, the analysis of the performance (according to the mechanisms and strategy chosen in the Beginning phase) of the participants during the execution of the activity, and the subsequent socialization of these results to the participants as feedback to be considered in subsequent activities. In this phase, the activity is also terminated with the corresponding closure. Activities are defined: *Validate the problem solution, Evaluate the participants' performance, Close the activity.*

  The milestone of this phase is:

  - Feedback: According to what was designed and planned in the Beginning phase, after executing the evaluation mechanisms, measurements of the participants' performance and the resolution of the problem are obtained, and information is analyzed and shared with the participants.

- Monitoring and assistance: THUNDERS contains a set of mechanisms, present in each of the phases, that allow the monitoring of each of the tasks, and their respective steps, to determine their complete and correct execution, in order to ensure that they are executed as established and planned, and thus guarantee the construction of shared understanding and the resolution of the problem, encouraging collaboration. In addition, THUNDERS contains a set of documents, guides, templates, and recommendations that provide assistance or support in the design, execution, validation, and evaluation of the collaborative activity, in order to guide those responsible for the tasks, and seeking to consider the ideal conditions for better results and better collaboration among participants.

4.3 THUNDERS Philosophy

The THUNDERS philosophy refers to those characteristics, pillars, and principles on which the THUNDERS conceptual level is based and according to which each of its elements are defined and based. In this sense, as mentioned above, the conceptual level defines, through the different elements and strategies, how to execute a collaborative activity from design to validation, in order to achieve each of the defined objectives and obtain better results at the end of the activity. Each of the characteristics, pillars, and principles are explained below (See Figure 4.3).

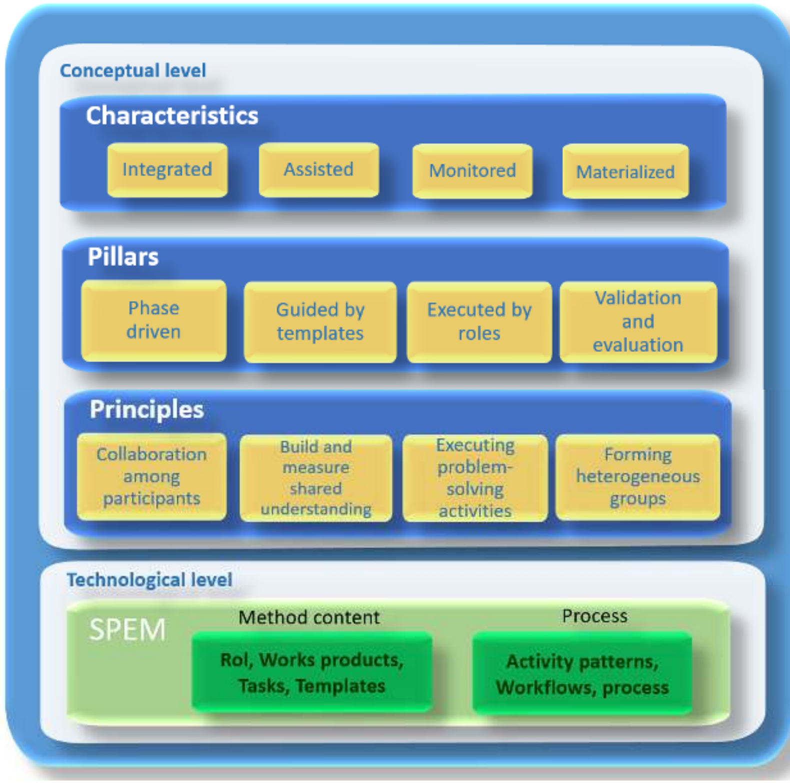


Figure 4.3 THUNDERS philosophy

4.3.1 Conceptual level

As previously stated, the conceptual level defines, through the different elements, how to execute from the design to the validation of a collaborative activity, in order to achieve each of the defined objectives and obtain better results at the end of said activity. That is why the conceptual level is based on characteristics, pillars, and principles that are explained below:

4.3.1.1 Characteristics

Integrated: To collaborate, group members have permanent interactions, exchanging ideas or points of view, for which it is necessary to have adequate communication, which generates that the group understands and agrees on the interpretation of the tasks to be performed, what and how they will do the work together, and understand the subject on which the activity is executed, i.e., it is necessary to build a shared understanding, to obtain as a consequence better levels of collaboration (Hsieh, 2006) (Kip & Schaefer, 2014). To obtain all of the above, THUNDERS integrates concepts and elements of collaboration and shared understanding so that from the construction of shared understanding a more assertive communication is generated, and therefore when working in a coordinated manner there is greater collaboration, to integrating specific elements for problem solving activities and defined for heterogeneous grouping of participants.

Assisted: Little attention has been paid to the systematic development of processes that lead to shared understanding within heterogeneous groups (Christiane Bittner & Leimeister, 2013) in addition to the lack of knowledge about the specific patterns that lead to their construction, and the non-existence of clear and adequate execution flows (Van den Bossche, Gijselaers, Segers, Woltjer, & Kirschner, 2011), which is why practitioners need guidance on how to evoke processes in a deliberate and repeated way (Bittner & Leimeister, 2014). THUNDERS provides elements to execute each of the phases of collaborative work in a guided way, providing a step-by-step that is supported by activities, tasks, work products, guidelines, and roles, in order to design, execute and validate a collaborative activity to successfully build shared understanding. In addition to offering a set of recommendations and assistance documents, which provide already built elements of the collaborative activity, or support according to the needs that arise.

Monitored: For a collaborative process to be effective, it is necessary to define a monitoring scheme to ensure, initially, that the activities and tasks of the process are performed according to what was previously planned and designed, and secondly to monitor the actions of all participants of the collaborative activity to know when and how to intervene to direct the activity when required (Scagnoli N. , 2005), (Collazos, Muñoz Arteaga, & Hernández, 2014). THUNDERS provides mechanisms to monitor the correct and complete execution of the process from the design of the collaborative activity to its validation, in order to ensure that each task is performed properly, this in order to guarantee that by following the tasks correctly, the problem is solved, the shared understanding is built and as a consequence, the collaborative process is improved.

Materialized: Shared understanding is one of the five critical challenges to be achieved within collaborative activities, critical due to, for example, the lack of overlapping experiences; the context, the shared language of actors; the ambiguous nature of problems; or the disruption of routines, which influences how a group forms and performs (Garfield & Alan R. , 2012). Future research should aim at a better understanding of the complex and still ambiguous phenomenon, its antecedents, and effects, thus generating promising opportunities to further develop techniques that leverage the benefits of shared understanding for effective group work (Bittner & Leimeister, 2014). THUNDERS contains work products, workflows, and mechanisms that enable shared understanding to be built and subsequently measured in a way that makes it tangible and materializable.

4.3.1.2 Pillars

Phase driven: Considering the need to have a systematic guide of what to do and how, in collaborative work (Christiane Bittner & Leimeister, 2013). it is necessary that the process is driven by phases, which allows giving a sequential order to the execution of such work. Where each phase has a milestone and in order to start the next phase, the previous one must be considered finished and completed, to obtain the necessary results in each one (Beginning, Developing, and Measuring).

Guided by templates: A template allows to perform a task according to how it was planned and structured, allowing to guide or build a predefined design or execution. Therefore, they are necessary to use them within the process, in order to guarantee and support those in charge of executing the different tasks, so that they can generate better actions and collect the appropriate information, following up on each of the templates defined in THUNDERS.

Executed by roles: For the execution of the process (each of its phases, activities, and tasks) it is necessary to have specific roles to take advantage of the necessary experience or knowledge of those who assume them (López Trujillo & André Ampuero, 2006). Therefore, THUNDERS is executed by means of roles and responsibilities, defined in each of the tasks, in order to have responsible persons in charge of defining the associated work products.

Validation and evaluation: *Validating* refers to the process of valuing the final product to determine whether it meets the needs, determining whether what was created or defined is correct (Roache, 1998). For its part, *evaluating* refers to the process of establishing, taking into account a set of criteria or standards, the value, importance, or significance of something (Sanyal & Wamique Hisam, 2018). THUNDERS relies on these concepts to validate the construction of shared understanding and problem solving to determine if what was obtained is correct and if corrective actions are needed. And to evaluate the performance of the participants, in order to analyze, according to established criteria, what was achieved in the activity. All these validations and evaluations are in order to have an analysis of each of the actions performed and the results obtained and, in this way, provide the corresponding feedback to the participants to be considered in subsequent activities and monitor each element for its correct execution.

4.3.1.3 Principles

Collaboration among participants: THUNDERS is specifically defined for collaborative work, which involves a group of people contributing their ideas and knowledge to achieve a common goal (Leeann, 2015). The idea of THUNDERS is to support building, monitoring, and assisting shared understanding to enhance computer-supported collaborative work in problem-solving activities.

Build and measure shared understanding: Each of the elements that are designed and executed within the collaborative process must promote the construction of shared understanding, for which THUNDERS provides assistance for this to happen and, in this way, improve the communication of the participants. In addition to this, THUNDERS provides mechanisms to measure shared understanding at two points in time, in order to validate understanding and, if there are problems, resolve them at the appropriate time. In the same way, mechanisms are provided to monitor that this understanding is maintained during the execution of the collaborative activity.

Executing problem-solving activities: Solving a problem collaboratively requires sharing the understanding and effort needed to reach a solution, pooling knowledge, skills, and efforts to reach that solution (Organization for economic co-operation and development (OECD), 2013). In this sense, THUNDERS provides the necessary mechanisms to support this collaborative problem-solving to be done in the most efficient way and to obtain the right results.

Forming heterogeneous groups: It is necessary to systematically bring together groups of people with mixed abilities to ensure a truly heterogeneous composition, with the objective of helping people with difficulties, allowing everyone to benefit from each other and to contribute their knowledge and experience in solving the problem (Barron, 2003). THUNDERS focuses on the creation of groups in which participants are guaranteed to have different and complementary skills, providing the mechanisms to identify them and subsequently form the groups considering specific characteristics of the participants.

4.3.2 Technological level

The technological level defines, through the different elements, the support to achieve the execution of each of the phases specified in THUNDERS, from the design to the validation of the collaborative activity. The technological level is mainly based on the use of SPEM 2.0 (Software Process Engineering Meta-Model) (OMG, 2007), as a metamodel and language for the formalization of THUNDERS by defining the content elements of the method and process.

SPEM 2.0 is a process engineering metamodel, as well as a conceptual framework, that provides the concepts necessary to specify, model, document, present, manage, exchange, and implement software development processes, and methods, which was used for the THUNDERS specification. In addition to SPEM 2.0, Eclipse Process Framework Composer (EPFC) (Haumer, 2007) a free platform developed under ECLIPSE and based on SPEM 2.0, was used to design, edit and maintain the processes formalized with SPEM 2.0. The use of EPFC provides a THUNDERS process in a computer-executable format, which: i) Facilitates human understanding and communication. ii) Facilitates reuse. iii) Supports process improvement. iv) Supports process management. v) Guides process automation. vi) Supports automatic execution. In addition, it allows the documentation and publication of THUNDERS through the generation of automatic documentation in web format.

4.3.2.1 Method content

THUNDERS defines a repository of reusable method content items, an organized collection of activities, tasks, work products, and guidelines, which define a knowledge base of method assets for the design, execution, and validation of collaborative activity and process content implementation in a uniform format.

4.3.2.2 Process

It allows to support the development, management, and evolution of THUNDERS processes, from the reuse of method content, it also provides the conceptual basis for selecting, adapting, and assembling processes for specific contexts.

The following Figure 4.4 shows the EPFC with the THUNDERS Plugin, with each of its content elements of the method and the process.

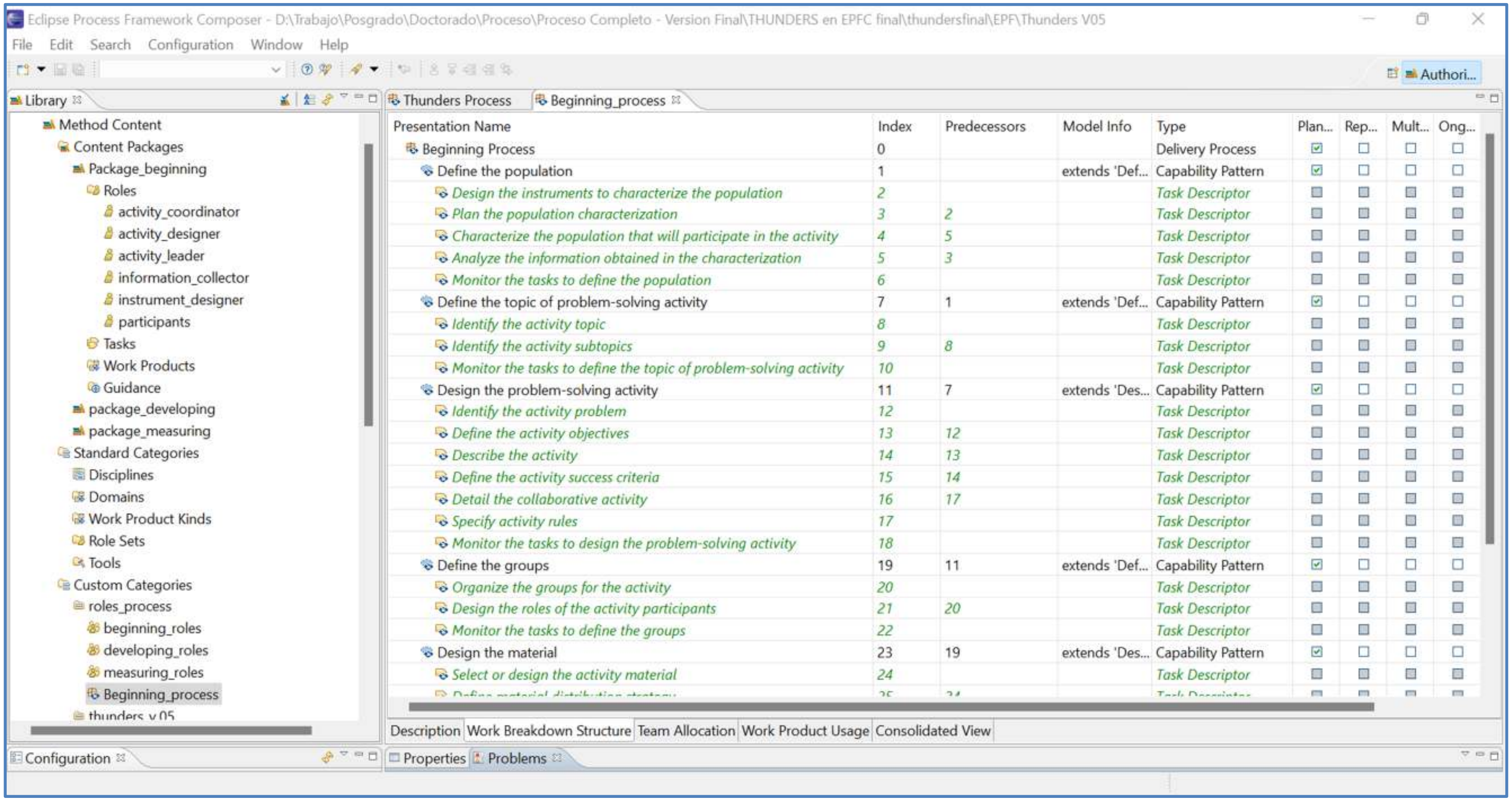


Figure 4.4 THUNDERS Plugin

4.4 THUNDERS support to identified requirements

Previously, some requirements were identified (in the Specification of method requirements section of 3.2.2 in Chapter 3), which were necessary to satisfy from the construction of the proposed process, that is why **Table 4.1Table 4.1** THUNDERS and support for every requirement

shows how the elements, and the THUNDERS philosophy that were used in its construction support each of these requirements and thus determine the object for which THUNDERS was built.

Method requirements	SME	Specification aspects	Characteristics aspect	Integrated	Assisted	Monitoring	Materialized	Phase driven	Guided by templates	Executed by roles	Validation and evaluation	Collaboration among participants	Build and measure shared Understanding	Executing problem-solving activities	Forming heterogeneous groups	SPEM 2.0
It should collect elements involved in collaborative work	X		X	X	X	X		X		X	X	X				
It must support each of the phases of collaborative work	X		X	X	X	X		X				X				X
It should allow building collaboration	X		X	X	X			X		X	X	X	X	X	X	
It should allow the construction and measurement of shared understanding	X		X	X	X		X		X		X		X			
It should provide monitoring and assistance	X		X		X	X						X				
It must support the formation of heterogeneous groups	X		X	X	X							X			X	
It must support the design of the collaborative activity	X		X	X	X			X	X			X		X		
It must be evolvable and maintainable		X														X
It must have a formal description		X														X
It should allow easy access to its definition		X														X
It must provide reusable components		X														X

Table 4.1 THUNDERS and support for every requirement

4.5 THUNDERS process

One of the main problems of collaborative work is that successful collaboration is difficult to achieve (Grudin, 1988) and does not occur as easily as might be expected (Rummel & Spada, 2005). Similarly, there are other difficulties such as, for example, not all members of a group participating effectively in the development of the idea with all the other members, the complexity of monitoring all the interconnected contributions of the participants, and the existence of barriers to work with people who are geographically distant (Persico, Pozzi, & Sarti, 2009). For this reason, it is necessary to improve computer-supported collaborative work, and for this, in this research, a literature review, a review of related works, an analysis of the context to detect opportunities for improvement was carried out, and then a proposal for a process with phases, activities, tasks, steps, and work products (inputs, outputs) that will allow the execution of collaborative work in problem-solving activities and thus allow reaching a shared understanding as an important determinant for the performance of collaborative groups was presented.

To model this process, the following conventions were used, based on the elements proposed by SPEM 2.0 (Ruiz & Verdugo , 2008) (See Table 4.2).

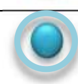
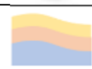
Notation	Element
	Start
	End
	Phase
	Activity
	Task
	Role
	Work Product

Table 4.2 SPEM 2.0 Conventions

The THUNDERS process has the following workflows for each of the phases and each workflow is composed of a set of defined activities. In the first phase, *Beginning*, THUNDERS starts with the design and specification of the collaborative activity and each of its elements, the coordination activities are defined, the strategies to be carried out during the collaborative activity, and the mechanisms that will allow evaluation of the performance of the participants and validate the shared understanding and the solution of the activity are designed (See Figure 4.5).

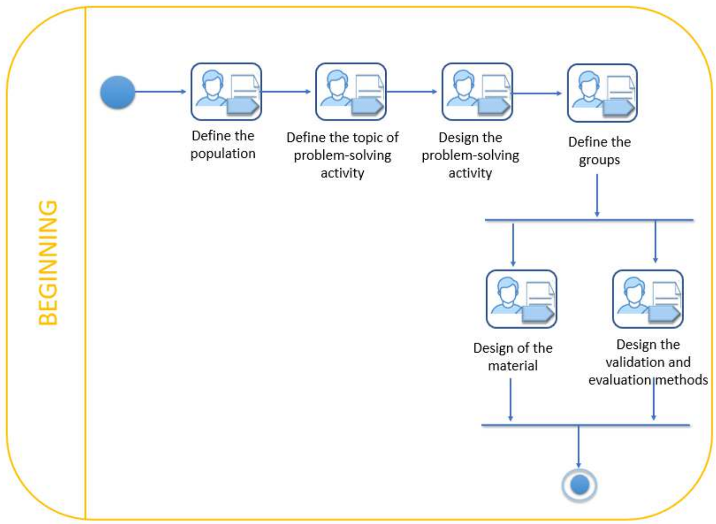


Figure 4.5 Beginning workflow

In the *Developing* phase, the collaborative activity is executed, performing all the activities planned in the Beginning phase, building, maintaining, and validating the shared understanding while collaboratively pursuing the solution to the established problem (See the phase workflow in Figure 4.6).

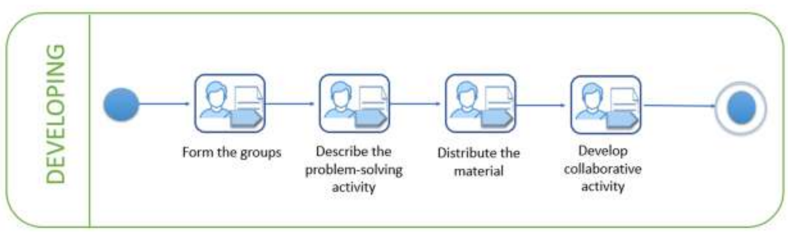


Figure 4.6 Developing workflow

To finalize the process, in the *Measuring* phase, the validation that the solution to the problem was obtained completely and correctly is carried out, in addition to evaluating the performance of the participants from different aspects and as a final activity, feedback is given to the participants of these validations and evaluations in order to end the collaborative activity (See the phase workflow in Figure 4.7).

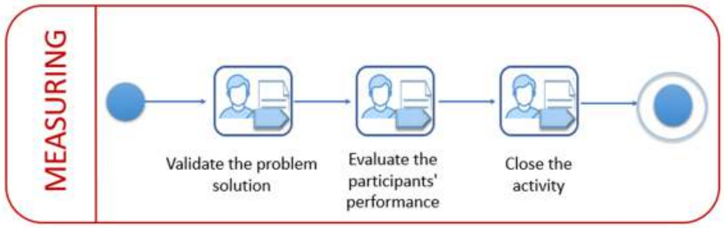


Figure 4.7 Measuring workflow

4.5.1 Beginning phase detail

From the previously shown workflows of each of the phases, this section of this chapter will be detailed the Beginning phase, since it is here where the design of all the necessary elements of a collaborative activity must be done so that they can later be executed in both the Development and Measurement phases (The details of all the other phases can be found in *Annex 3*).

THUNDERS is defined according to what is established by SPEM 2.0, therefore, from the activity flow shown, each activity is composed of a new task flow, tasks are a content element of the method that indicates a definition of work, which is performed by roles, and are in charge of transforming input work products into output work products (OMG, 2007). A task focuses on what needs to be done to achieve a given purpose, usually associated with one or more artifacts (Solano, Granollers, & Collazos, 2015).

THUNDERS provides assistance documents to execute the process, such as templates and guidelines, in such a way, that to help its use, each of these formats has a color code that allows determining whether each of its items is information to contextualize, is mandatory information or not to be filled in, is information that is obtained from previous tasks, or is obtained from previously completed forms. The color code defined is shown below (See Figure 4.8):

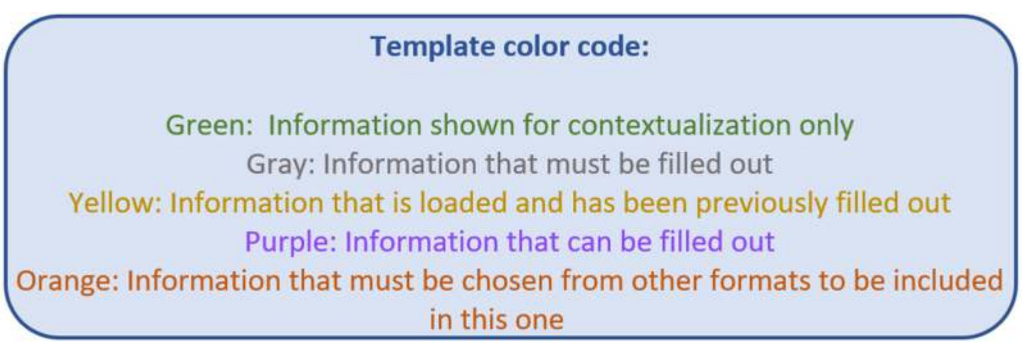


Figure 4.8 Color code of support templates

Below are the task flows for each activity with a summary of the information defined for each one (The detailed information can be found in *Annex 3*). It is important to note that each task was defined with the following information (See Table 4.3).

Task Name	*The representative name of the task*
Identifier	*A number that identifies the task*
Description	*A brief description and justification for the task*
Inputs	*Work products required to execute the task*
Outputs	*Work products that are results of the executing of the task*
Roles	*Those responsible for executing the task, either the support role and the artifact manager and, if it exists, the secondary executors.*
Steps	*1. Step 1* *2. Step 2* *3. ….*
Work products	*All assistance or support documents*

Table 4.3 Information defined for each task

4.5.1.1 Activity: Define the population

To carry out a collaborative activity, it is necessary to initially create groups to solve the problem of the collaborative activity. A group is a set of people who cooperate with each other and maintain a relationship or continuous communication (Razmerita & Brun, 2011). For this research, heterogeneous groups will be created, i.e. a type of uniform distribution of members with different values of the selected characteristics (Cohen & Lotan, 2014). For this reason, this activity will allow defining the characteristics of the participants that will be considered for the conformation of the groups, in addition to the design of the instruments that will allow knowing the participants and thus group them in a systematic way, with mixed abilities to ensure a truly heterogeneous composition. The flow of tasks for this activity is shown in Figure 4.9.

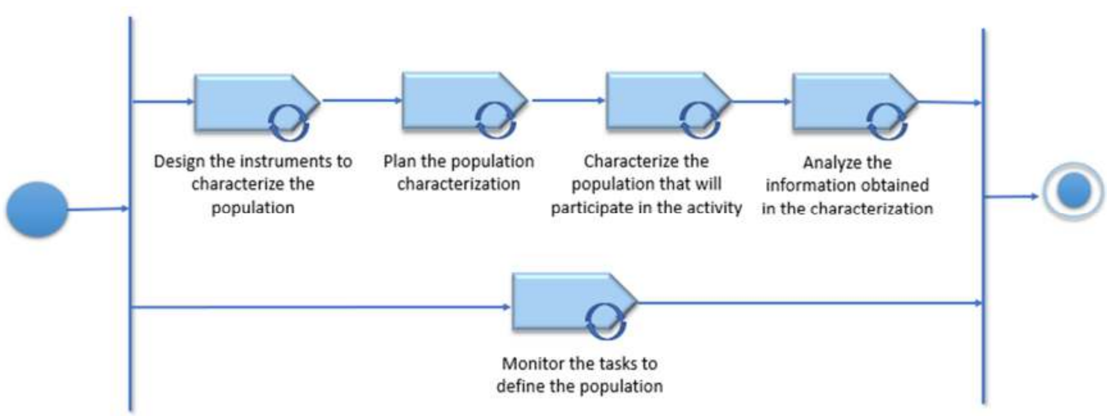


Figure 4.9 The task flow of the activity Define the population

The task: Design the instruments to characterize the population, which will make it possible to determine the characteristics to be analyzed in the population, and subsequently design or choose the instruments needed to determine them. If the designer does not want to do the design from scratch with the support of a recommendations document, the task also provides help with instruments already defined to be chosen, such as:

- Instrument - Intellectual skills
- Instrument - Learning styles
- Instrument - Personal information
- Instrument - Personality traits by William Marston
- Instrument - Personality traits

The task: Plan the population characterization, will allow planning and guiding the characterization to be carried out, defining a route, which considers the characteristics and instruments defined and designed in the previous task.

The task: Characterize the population that will participate in the activity, will make it possible to execute the actions and the previously designed plan, obtaining the information corresponding to the characteristics of the population, and applying the defined instruments.

The task: Analyze the information obtained in the characterization, will make it possible to analyze the values obtained in the formats applied and with them to interpret the characteristics present in each participant. It will also allow determining the way in which these characteristics will be considered for the conformation of heterogeneous groups. For this task, assistance is provided to interpret the values obtained in the instruments provided by the process.

The task: Monitor the tasks to define the population, will allow monitoring each of the other tasks of this activity, allowing to determine the completeness and correctness of each executed step. To this end, checklists are provided to monitor and define actions if it is necessary to correct anything that has been done.

The following Table 4.4 shows the summary of the names of the tasks, roles, inputs, outputs, and assistance documents used in this activity, the detail, and specification of each one can be found in Annex 3.

<table>
<tr><th>Task</th><th>Roles</th><th>Inputs</th><th>Outputs</th><th>Work products</th></tr>
<tr><td rowspan="6">Design the instruments to characterize the population</td><td rowspan="4">Instrument designer</td><td rowspan="6">Plan for the design of instruments to characterize the population</td><td rowspan="3">Plan for the design of instruments to characterize the population (Filled out)</td><td>Recommendations for designing the instruments</td></tr>
<tr><td>Instrument - Personality traits</td></tr>
<tr><td>Instrument - Personality traits - by William Marston</td></tr>
<tr><td rowspan="3">Instrument to characterize the population</td><td>Instrument - Learning styles</td></tr>
<tr><td rowspan="2">Activity coordinator</td><td>Instrument - Personal information</td></tr>
<tr><td>Instrument - Intellectual skills</td></tr>
<tr><td rowspan="3">Plan the population characterization</td><td rowspan="3">Instrument designer</td><td>All participants list</td><td rowspan="3">Information gathering plan (Filled out)</td><td rowspan="3">--</td></tr>
<tr><td>Plan for the design of instruments to characterize the population (Filled out)</td></tr>
<tr><td>Information gathering plan</td></tr>
<tr><td rowspan="5">Characterize the population that will participate in the activity</td><td rowspan="3">Information collector</td><td>Plan for the design of instruments to characterize the population (Filled out)</td><td rowspan="5">List of the values of the characteristic analyzed in the participants (Filled out)</td><td rowspan="5">--</td></tr>
<tr><td>Instrument to characterize the population</td></tr>
<tr><td>All participants list</td></tr>
<tr><td rowspan="2">Participants</td><td>Information gathering plan (Filled out)</td></tr>
<tr><td>List of the values of the characteristic analyzed in the participants</td></tr>
<tr><td rowspan="3">Analyze the information obtained in the characterization</td><td>Activity coordinator</td><td rowspan="2">List of the values of the characteristics analyzed in the participants (Filled out)</td><td rowspan="3">Results of the analysis of the information obtained in the characterization (Filled out)</td><td rowspan="3">Recommendations for analyzing the information obtained in the characterization</td></tr>
<tr><td>Information collector</td></tr>
<tr><td>Activity leader</td><td>Results of the analysis of the information obtained in the characterization</td></tr>
<tr><td rowspan="4">Monitor the tasks to define the population</td><td>Activity coordinator</td><td>Monitor the design of instruments to characterize the population</td><td>Monitor the design of instruments to characterize the population (Filled out)</td><td rowspan="4">--</td></tr>
<tr><td>Activity leader</td><td>Monitor the planning the population characterization</td><td>Monitor the planning the population characterization (Filled out)</td></tr>
<tr><td rowspan="2">Information collector</td><td>Monitor knowing the population that will participate in the activity</td><td>Monitor knowing the population that will participate in the activity (Filled out)</td></tr>
<tr><td>Monitor the information analysis obtained in the characterization</td><td>Monitor the information analysis obtained in the characterization (Filled out)</td></tr>
</table>

Table 4.4 Elements of the activity "Define the population"

4.5.1.2 Activity: Define the topic of problem-solving activity

Collaborative problem-solving activity is "... a joint activity in which groups execute a series of steps to transform a current state into a desired goal state" (Braunschweig & Seaman, 2014), consisting of two parts, "collaboration" and "problem-solving" (Bittner & Leimeister, 2014). These collaborative activities must have a theme or issue, which allows determining what problem is to be solved around it. With this, this activity will allow defining and structuring of the topic and subtopics that the collaborative activity will deal with as an integrating axis and as a means to plan and guarantee the systematized planning of what will be dealt with during the collaborative activity. The task flow of this activity is presented in Figure 4.10.

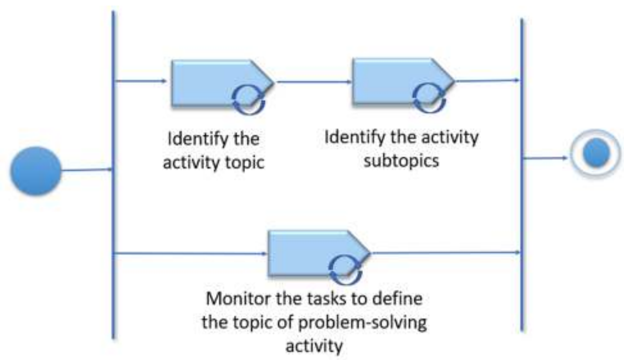


Figure 4.10 The task flow of the Define the topic of problem-solving activity

The task: Identify the activity topic, will allow defining the main theme and its information, which will be used to determine what the collaborative activity will be developed and dealt with.

The task: Identify the activity subtopics, will allow defining which subtopics should be considered for the activity with their respective information, considering that the topic is the core of what is going to be developed in the collaborative activity and that it in turn encompasses several subtopics, which will support the main topic and help to structure it better.

The task: Monitor the tasks to define the topic of problem-solving activity, like the monitoring task of the previous activity (and works the same for each subsequent monitoring task presented), will allow the tracking of each of the other tasks proposed and foreseen in this activity.

The following Table 4.5 shows the summary of the names of the tasks, roles, inputs, outputs, and assistance documents used in this activity.

Task	Roles	Inputs	Outputs	Work products
Identify the activity topic	Instrument designer	Results of the analysis of the information obtained in the characterization (Filled out)	Topic and its information (Filled out)	--
		Topic and its information		
Identify the activity subtopics	Instrument designer	Topic and its information (Filled out)	Subtopics and its information (Filled out)	--
		Subtopics and its information		
Monitor the tasks to define the topic of problem-solving activity	Activity coordinator	Monitor the identification of the activity topic	Monitor the identification of the activity topic (Filled out)	--
	Activity leader	Monitor the identification of the activity subtopics	Monitor the identification of the activity subtopics (Filled out)	

Table 4.5 Elements of the activity "Define the topic of problem-solving activity"

4.5.1.3 Activity: Design the problem-solving activity

This activity will guide and structure the design of the collaborative activity through clear and detailed steps. It will also guide the definition of the problem, the rules, the estimated execution time, and the success criteria that will define the completion of the activity. All this is in order to obtain a collaborative activity designed with all the necessary elements, which promotes the construction of a shared understanding among the participants to achieve the established objectives and the necessary collaboration to solve the problem posed. The task flow of this activity is presented in Figure 4.11**¡Error! No se encuentra el origen de la referencia.**.

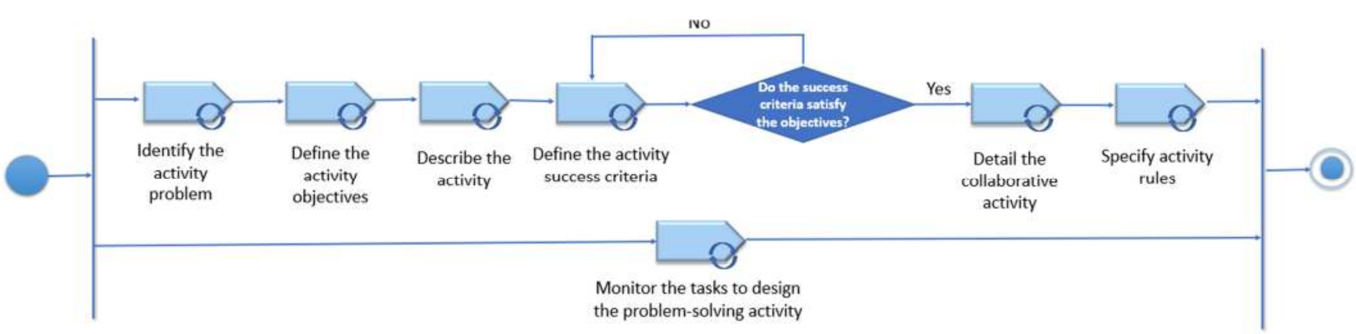


Figure 4.11 The task flow of the Design the problem-solving activity

The task: Identify the activity problem, will allow identifying the problem (which refers to a difficult situation to which a solution must be found that is not obvious (Cañadas Santiago, et al., 2002)) to be solved, as well as to know its causes and consequences. This task can also identify all possible solutions to the problem posed, transforming the problem tree into possible solutions through a tree of objectives.

The task: Define the activity objectives, will make it possible to clearly define the objectives (which refer to the goal or purpose to be achieved (Lund, Collazos, & Ormeño, 2012)) to be reached with the collaborative activity, as well as to define criteria for their fulfillment or non-fulfillment. The objectives will be divided into problem-solving objectives, which refer to the needs that will be solved at the end of the activity, and to those competencies or skills that will be developed by participating in the activity; knowledge objectives, which are related to the topics selected to be developed and the knowledge domain related to them; and finally collaboration objectives, which refer to the social and interpersonal skills that will be developed and promoted during the activity.

The task: Describe the activity, will allow defining what the participants will do in the collaborative activity to complete the solution of the problem. In this design, it is necessary to consider that the activity should promote the construction of a shared understanding, so that the necessary and correct collaboration is obtained to solve the problem. If the designer does not want to describe the collaborative activity from scratch following recommendations, the task also provides assistance with descriptions of predefined activities to choose from, such as:

- *Description of the activity - Agile Inception*: is a group technique that allows focusing all participants on the same objective, reducing many of the uncertainties and ignoring non-value issues, helping to analyze the risks of the problem, those involved, and the elements that are within the scope, and those that should not be taken into account, the cost, the priorities that should be considered, to determine the feasibility of implementing a solution, analyzing the possible solutions, and putting in common the expectations of all, to subsequently implement the most appropriate solution.
- *Description of the activity – Brainstorming*: is a group technique in which the creation of new ideas is produced, by encouraging participation and creative thinking about them. It consists of giving free rein to a brainstorm of ideas and saying them without censorship, with freedom, and without any limitation, and then these ideas are analyzed and valued as a group or can be completed by another.
- *Description of the activity - Impact mapping*: is a group technique that allows to graphically define the needs, the problem, and its respective solution proposal to identify the actors, their impact, and the actions to be carried out, in order to identify the correct information and determine precisely the solution to the problem, concentrating the efforts in working on the crucial, ignoring the superfluous details.
- *Description of the activity – Storytelling:* is a group technique where the problem, its context, and the objective of the activity are narrated in the form of a motivating and exciting story, creating a sequence of facts, real or fictitious, creating an atmosphere that envelops and captivates. The actors or stakeholders are determined, their experiences,

their location, and a possible solution is proposed, describing the characters, the place, and the facts to be developed, in order to obtain a better solution that fits the identified.

- *Description of the activity - The extended lexical of language model*: is a group technique that allows to represent and document a set of symbols (words or phrases used) that represent the language of the context, that is, to identify the terms that are used in the context, in order to clarify important elements of both the problem and the objective of the activity, establishing a common language, becoming familiar with the language of the domain and thus, through the use of problem scenarios (which are partial descriptions of the actions or needs that occur in the problem) identify possible solutions and choose the one that best suits those scenarios.
- *Description of the activity - The three C*: is a group technique based on three important elements, one of them refers to the creation of Cards, where the necessary information is specified (stakeholders, the need to be solved, and what is expected to be obtained), the second one refers to The Conversation, where each group must have an expert on the problem and the activity, to interact with him/her and be able to know as much information as possible. The last C refers to Confirmation, where the group agrees on the understanding of the activity, the choice of the solution, and its implementation.

All of the six collaborative activities proposed above, as assisting documents for the activity description, contain the following elements within their specification:

- *What does the collaborative activity refer to?* It defines what the proposed collaborative activity is intended to achieve and its objective.
- *Choose this activity*: This refers to those cases in which the specified collaborative activity could be chosen, depending on the expected results, the type of problem, the type of solutions that can be obtained, the context and information of the activity, etc.
- *Do not choose this activity*: This refers to those cases where it is not recommended to choose the specified collaborative activity.
- *Activity description*: This refers to a detailed, brief, and orderly explanation of what participants are to do in the proposed problem-solving activity. The description serves to acclimate the participants, setting the stage for the specific tasks that will then be explained (in a later task) more clearly. These collaborative activities should promote a shared understanding among participants, so both the activities that are designed from scratch and the activities proposed by THUNDERS should follow the following structure (with a definition of activities and tasks, see Figure 4.12) and depending on the proposed activity, new elements are included or the definition of each one is adapted according to what is required.

Figure 4.12 Structure for executing a collaborative problem-solving activity

In "Specify the problem to solve" activity, the problem to be solved as a result of the collaborative activity is socialized.

In the activity "Understanding the activity", both the problem and the objective of the activity are understood. In the task "**Individual understanding**", each person reads and understands individually the collaborative activity, in "**Resolution of doubts**" each person, if he/she has doubts according to what was read, asks for clarifications from the groupmates, and if they do not solve them, he/she must ask the person in charge, in "**Share**", each participant shares that individual understanding, after the intervention of all, in "**Debate**", a discussion or debate is held where each participant, with arguments, spontaneously defines those points on which he/she disagrees, in "**Conflict resolution**" the group identifies the conflict, presents ideas, negotiation is carried out, if an agreement is not reached, conciliation is sought with the vote, if it is not resolved, a mediator enters, who will act as a communication channel to reach an agreement, in "**Group understanding**" the understanding of the activity to be developed is formalized in a deliverable, with the support of all participants. This is followed by a "**Debate**" where everyone's point of view on what has been defined is discussed, and then "**Conflict resolution**" is carried out if there are discrepancies, where a final agreement is reached.

In the activity “Select the solution to the problem”, the participants will select the proposed solution to the problem that they will subsequently implement. For this, the same previous structure of the tasks is followed, considering that in the task "**Proposal of individual solutions**" each participant makes one or several solution proposals to the problem, and after solving the conflicts presented, in the task "**As a group selects**

the solution to the problem" one of all the individual proposals is selected, which is formalized with the support, input, and collaboration of all participants.

In the activity “Implement the problem solution”, the participants will jointly implement the previously chosen solution. Initially, within the group, the tasks that are necessary to implement the selected solution are determined, in the task "**Individual tasks**" each participant performs the tasks that contribute to the solution of the problem, and after resolving the conflicts presented, in the task "**Group solution**" the implementation of the solution of the problem is formalized with the support, contribution, and collaboration of all participants, thus solving the problem of the collaborative activity.

In the activity “Validate the problem solution”, the participants will validate the solution that was implemented to determine if it solves the problem posed, in the task "**Individual validations**" each participant performs an individual validation, and after resolving the conflicts presented, in the task "**Group validations**" the validation that the implemented solution complies or not with the solution to the problem is formalized with the support, contribution, and collaboration of all the participants, the validation that the implemented solution complies or does not comply with the solution to the problem.

The task: Define the activity success criteria, will allow defining those conditions, requirements, or expected results (they can be products, behaviors, or deliverables of the work) that will help determine whether the activity has been successfully completed or not, and that must be verified throughout the execution of the collaborative activity.

The task: Detail the collaborative activity, will allow determining the details of the collaborative activity, specifying the tasks, steps, sequence, order, inputs and outputs, and formats necessary for its execution. With this, it will be possible to plan and structure the activities and tasks to be carried out, considering that they must ensure the achievement of a shared understanding among the participants. If the designer has previously selected any of the six collaborative activities offered by THUNDERS, the task offers assistance with the detail of each collaborative activity with its respective information, and formats needed to execute it. THUNDERS provides the detail of each collaborative activity:

- Collaborative activity detail - Agile Inception
- Collaborative activity detail – Brainstorming
- Collaborative activity detail - Impact mapping
- Collaborative activity detail – Storytelling
- Collaborative activity detail - The extended lexical of language model

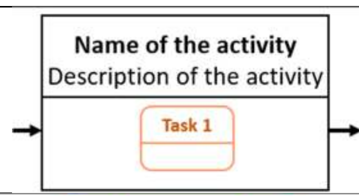
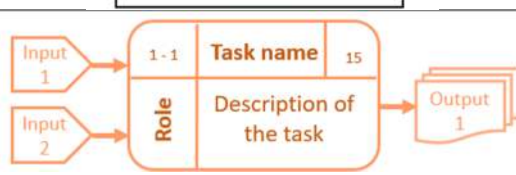
- Collaborative activity detail - The three C

Each collaborative activity offered by THUNDERS (Agile Inception, Brainstorming, Impact Mapping, Storytelling, The extended lexical of language model, and The three C) has a set of defined activities and tasks, which were described in the process task "Describe the activity". In this sense, the details of the collaborative activities provided by the process contain the following information (See Table 4.6, the details of each collaborative activity can be found in *Annex 4*):

Name of the activity	Name defined in the description of the collaborative activity
Description of the activity:	Brief definition of the objective and justification of the collaborative activity
Each collaborative activity has a set of defined tasks, each task containing the following information:	
Identifier	Number assigned to identify the task
Name of the task	The representative name of the task
Description of the task	A brief description and justification of the task
Estimated time	The estimated time it will take to complete this task
Roles	Person in charge of executing the task
Is it a collaborative task?	It is determined whether the task is performed with the support of other participants or whether it is done individually
Inputs	Work products required to execute the task
Outputs	Work products that are the results of executing the task
Steps	Set of advances that must be executed to accomplish the objective of the task
Execution formats	Each step, if required, contains a set of formats that are provided to guide its execution

Table 4.6 Information contained in each collaborative activity proposed by THUNDERS

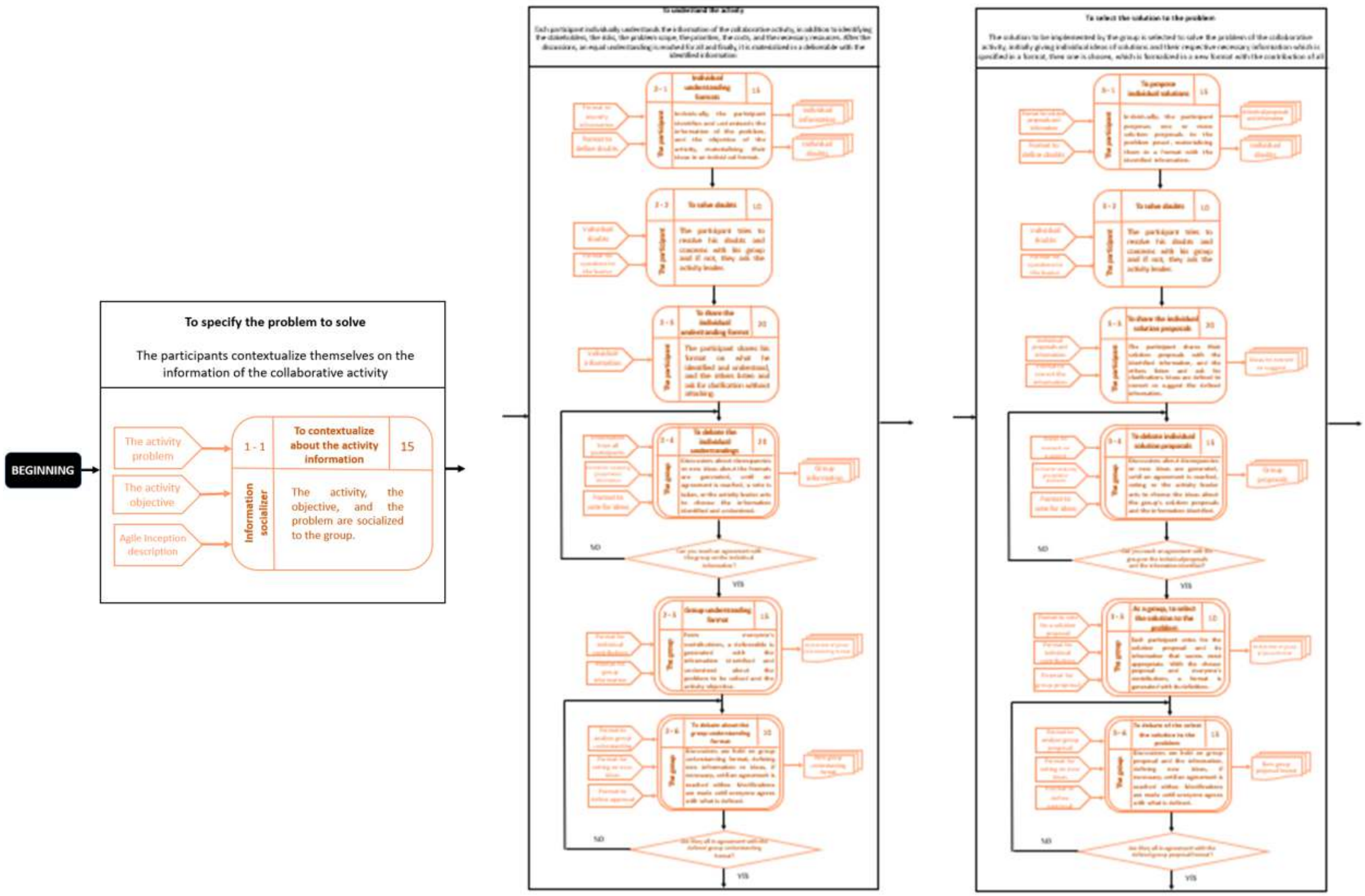
In addition to the above, each of these six collaborative activities proposed by THUNDERS to build shared understanding and solve a problem were modeled using a modeling notation, which was based on HAMSTERS (Human-centered Assessment and Modeling to Support Task Engineering for Resilient Systems) (Martinie, Palanque, & Winckler, 2011) adapting some of its elements. The elements used for the modeling were those shown in Table 4.7:

Notation	Element	Notation	Element
	Start of collaborative activity		Activity structure
	End of collaborative activity		Task structure - A rectangle is an individual task; double rectangle is a collaborative task. On the right side of the task is the identifier, on the left side the estimated execution

			time.
	Products needed to execute the task		Products obtained from executing the task

Table 4.7 Conventions for modeling collaborative activities

Each of the collaborative activities was modeled following the above notation, an example of the modeling of the *"Agile Inception"* activity is shown below (See Figure 4.13) (the modeling of the other activities can be seen in *Annex 5*).



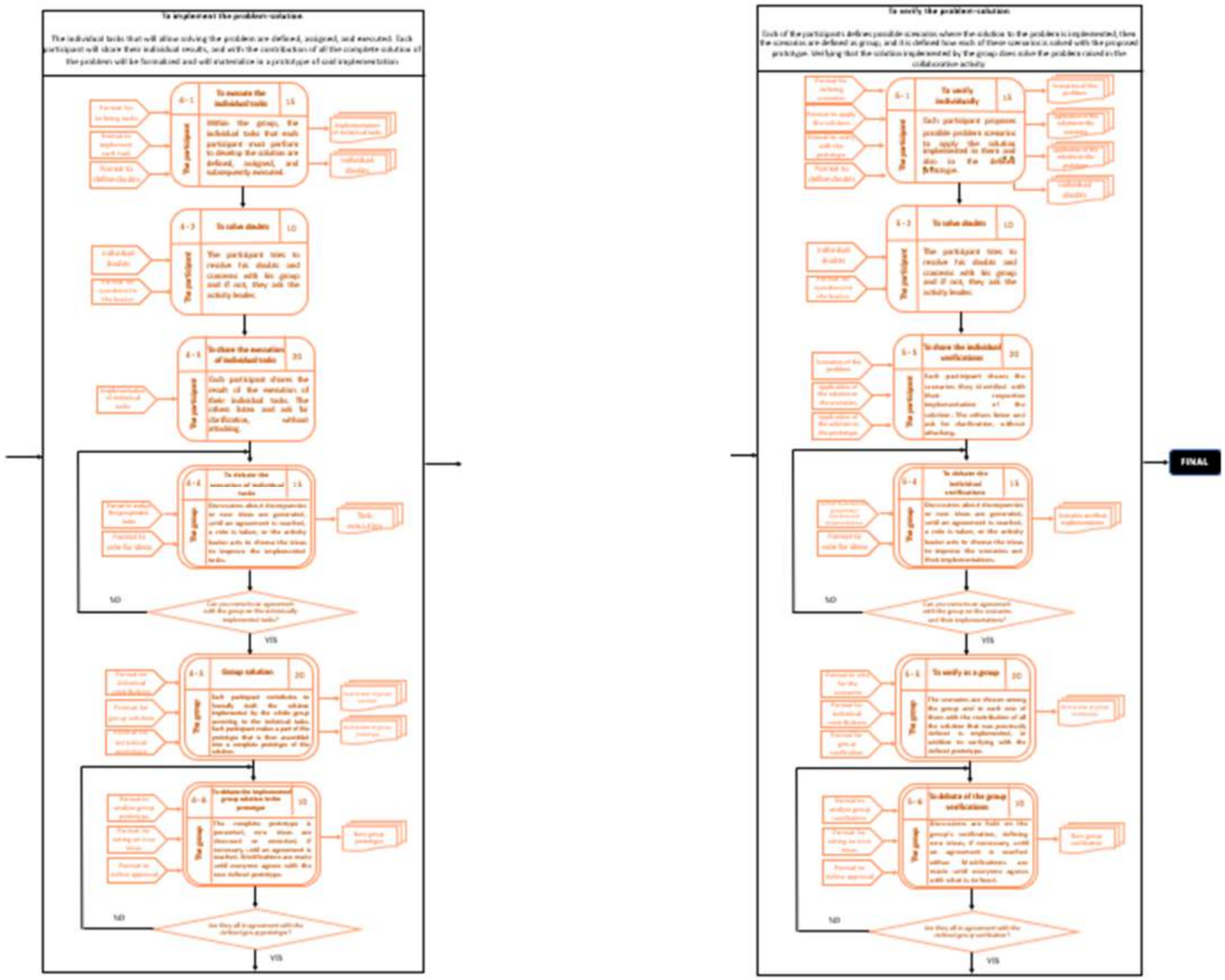


Figure 4.13 Modeling of the collaborative activity "Agile Inception"

The task: Specify activity rules, will allow defining the rules, restrictions, norms, and conditions to control behaviors, communication, frequency of participation, discussions, the start and end of each task, and the elements of the activity, as well as defining the necessary strategy to socialize these rules. The task provides as assistance a document of recommendations that will support the definition of the most appropriate rules.

The following Table 4.8 shows the summary of the names of the tasks, roles, inputs, outputs, and assistance documents used in this activity.

Task	Roles	Inputs	Outputs	Work products
Identify the activity problem	Activity designer	Results of the analysis of the information obtained in the characterization (Filled out)	Problem and its information (Filled out)	--
	Instrument designer	Topic and its information (Filled out)		
		Subtopics and its information (Filled out)		
		Problem and its information		
Define the activity objectives	Activity designer	Definition of types of objectives	Definition of types of objectives (Filled out)	--
	Activity coordinator			
Describe the activity	Activity designer	Results of the analysis of the information obtained in the characterization (Filled out)	Activity description and its information (Filled out)	Recommendations to describe the activity
		Topic and its information (Filled out)		Description of the activity - Brainstorming
				Description of the activity - The three C
	Activity leader	Subtopics and its information (Filled out)		Description of the activity - Impact mapping
			Description of the activity	Description of the activity - Storytelling
		Problem and its information (Filled out)		Description of the activity - Agile Inception
		Activity description and its information		Description of the activity - The extended lexical of language model
Define the activity success criteria	Activity designer	Activity description and its information (Filled out)	Success criteria description (Filled out)	--
	Activity coordinator	Definition of types of objectives (Filled out)		
		Success criteria description		
Detail the collaborative activity	Activity designer	Activity description and its information (Filled out)	The detailed specification of the collaborative activity (Filled out)	Recommendations to detail the collaborative activity
				Collaborative activity detail - Brainstorming
		Definition of types of objectives (Filled out)		Collaborative activity detail - The three C
				Collaborative activity detail - Impact mapping
	Activity leader	Success criteria description (Filled out)	Collaborative activity detail	Collaborative activity detail - Storytelling
				Collaborative activity detail - Agile Inception
		The detailed specification of the collaborative activity		Collaborative activity detail - The extended lexical of language model

Specify activity rules	Activity designer	Definition of types of objectives (Filled out)	Activity rules description (Filled out)	Recommendations to specify activity rules
	Activity coordinator	The detailed specification of the collaborative activity (Filled out)		
		Activity rules description		
Monitor the tasks to design the problem-solving activity	Activity coordinator	Monitor the identification of the activity problem	Monitor the identification of the activity problem (Filled out)	--
	Activity leader	Monitor the description of the activity	Monitor the description of the activity (Filled out)	
	Instrument designer	Monitor the defining of the activity objectives	Monitor the defining of the activity objectives (Filled out)	
		Monitor the defining of the activity success criteria	Monitor the defining of the activity success criteria (Filled out)	
	Activity designer	Monitor the definition of the collaborative activity details	Monitor the definition of the collaborative activity details (Filled out)	
		Monitor the specification of the activity rules	Monitor the specification of the activity rules (Filled out)	

Table 4.8 Elements of the activity "Design the problem-solving activity"

4.5.1.4 Activity: Define the groups

In order to carry out a collaborative activity, it is necessary to form the groups that are going to carry out the activity. A collaborative workgroup is a group of three or more people who interact in a dynamic and interdependent way with respect to a goal and objectives, where each one acquires specific responsibilities or roles. To this end, the choice of group members can be crucial to promoting the quantity and quality of interactions that occur in the collaborative process (Rojas Díaz, Zambrano Matamala, & Salcedo Lagos, 2020). In this sense, this activity will allow organizing the groups that will carry out the proposed activity, considering the previously analyzed characteristics of the participants, allowing grouping them in such a way that the heterogeneity of their characteristics allows their differences to give rise to the interaction and collaboration necessary to achieve common goals (Razmerita & Brun, 2011). This organization must also consider its size, the distribution of participants, and the selection of those who will make up each group, in addition to the design of roles with their respective responsibilities. The task flow of this activity is presented in Figure 4.14.

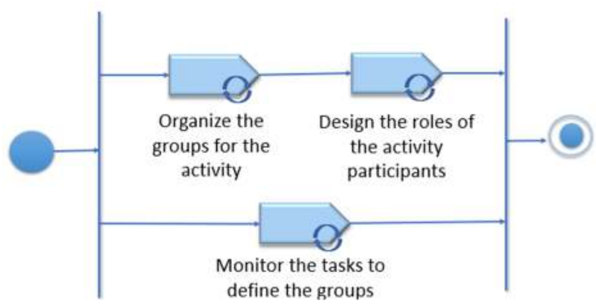


Figure 4.14 The task flow of the Define the groups activity

The task: Organize the groups for the activity, will allow defining the size of each group, forming them, and organizing each participant in one of them, depending on the needs of the collaborative activity and the characteristics previously identified in the participants, with the objective that the groups are organized in a heterogeneous way. The task provides assistance with a recommendations document, where a heterogeneous group formation strategy is defined that can support the designer.

The task: Design the roles of the activity participants, will allow designing and assigning to each participant of the group their responsibilities (it is a function that someone performs, a set of expected and attributed behavior patterns (Durán, Calo, & Argañaraz, 2012)), considering the proposed objectives, the characteristics, skills, and individual potential of each participant. It also allows defining the role rotation strategy if required. The task provides assistance with a document of recommendations, where roles are defined that are designed to foster shared understanding, collaboration, and support problem-solving.

The following Table 4.9 shows the summary of the names of the tasks, roles, inputs, outputs, and assistance documents used in this activity.

Task	Roles	Inputs	Outputs	Work products
Organize the groups for the activity	Activity designer	Results of the analysis of the information obtained in the characterization (Filled out)	The groups design (Filled out)	Recommendations to organize the groups for the activity
	Activity leader	The detailed specification of the collaborative activity (Filled out)		
		The groups design		
Design the roles of the activity participants	Activity designer	Definition of types of objectives (Filled out)	Design and assignment of roles (Filled out)	Recommendations to design the roles of the activity participants
	Activity leader	Activity description and its information (Filled out)		
		The groups design (Filled out)		
		Design and assignment of roles		
Monitor the tasks to define the groups	Activity coordinator	Monitor the organization of the groups for the activity	Monitor the organization of the groups for the activity (Filled out)	--
	Activity leader			
	Activity designer	Monitor the design of the participants roles	Monitor the design of the participants roles (Filled out)	

Table 4.9 Elements of the activity "Define the groups"

4.5.1.5 Activity: Design the material

A collaborative activity may require materials or resources for its realization, motivating the participant to use his or her creativity, encouraging the use of additional resources to generate collaboration, facilitate and support the development of the activity and, consequently, the resolution of the problem. In this sense, this activity will allow selecting or designing the materials that will be necessary to support the participants and defining a strategy for their distribution. The task flow of this activity is presented in Figure 4.15**¡Error! No se encuentra el origen de la referencia.**.

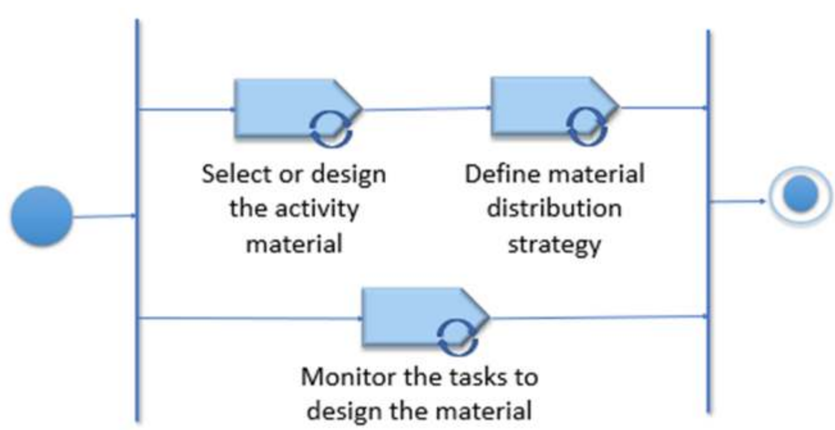


Figure 4.15 The task flow of the Design the material activity

The task: Select or design the activity material, will allow designing, selecting a previously defined one, or modifying according to the needs, the materials necessary to support the participants to carry out the collaborative activity.

The task: Define material distribution strategy, will allow, according to the material defined in the previous task, the design of the distribution strategy of such material, to ensure that the collaborative activity is carried out jointly and that it supports the solution of the problem. The task provides assistance through recommendations for the most appropriate distribution of the material considering the activity, the problem, the participants, and the objectives.

The following Table 4.10 shows the summary of the names of the tasks, roles, inputs, outputs, and assistance documents used in this activity.

<table>
<tr><th>Task</th><th>Roles</th><th>Inputs</th><th>Outputs</th><th>Work products</th></tr>
<tr><td rowspan="3">Select or design the activity material</td><td>Instrument designer</td><td>The detailed specification of the collaborative activity (Filled out)</td><td rowspan="3">Definition of material to use (Filled out)</td><td rowspan="3">--</td></tr>
<tr><td rowspan="2">Activity designer</td><td>Design and assignment of roles (Filled out)</td></tr>
<tr><td>Definition of material to use</td></tr>
<tr><td rowspan="3">Define material distribution strategy</td><td>Activity designer</td><td>Design and assignment of roles (Filled out)</td><td rowspan="3">Material distribution strategy (Filled out)</td><td rowspan="3">Recommendations to define the material distribution strategy</td></tr>
<tr><td rowspan="2">Activity leader</td><td>Definition of material to use (Filled out)</td></tr>
<tr><td>Material distribution strategy</td></tr>
<tr><td rowspan="4">Monitor the tasks to design the material</td><td>Activity coordinator</td><td rowspan="2">Monitor the selection or design of the activity material</td><td rowspan="2">Monitor the selection or design of the activity material (Filled out)</td><td rowspan="4">--</td></tr>
<tr><td>Activity leader</td></tr>
<tr><td>Instrument designer</td><td rowspan="2">Monitor the definition of the material distribution strategy</td><td rowspan="2">Monitor the definition of the material distribution strategy (Filled out)</td></tr>
<tr><td>Activity designer</td></tr>
</table>

Table 4.10 Elements of the activity "Design the material"

4.5.1.6 Activity: Design the validation and evaluation methods

To determine the success and culmination of a collaborative activity, it is necessary to carry out a process of validation and evaluation of the fulfillment of the different elements that guarantee the fulfillment of the different planned objectives. That is why this activity will allow defining the strategy, criteria, and mechanisms that will be used to validate the fulfillment of the problem that was intended to be solved with the collaborative activity, validate that the shared understanding was built correctly and, in the moments, defined for its analysis, as well as to evaluate the individual and group performance achieved by the participants during the execution of the activity. This activity will also define the strategies and mechanisms to provide feedback to the participants on the actions performed, their mistakes, successes, and other necessary elements to be considered in future collaborative activities. The task flow of this activity is presented in Figure 4.16.

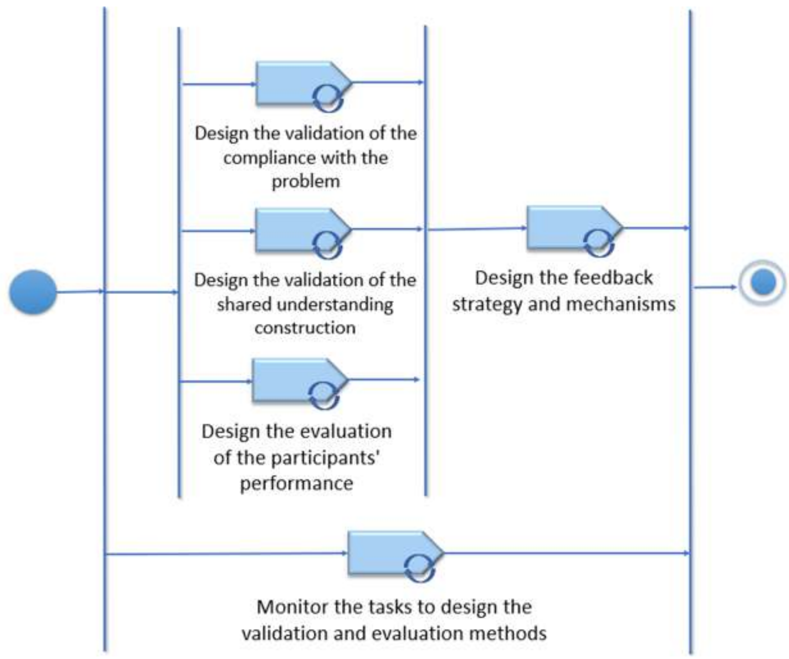


Figure 4.16 The task flow of the Design the validation and evaluation methods activity

The task: Design the validation of the compliance with the problem, will allow designing a strategy, the corresponding criteria, the mechanisms to carry it out, and will allow determining the moments in which this validation will be carried out, with the objective of determining the fulfillment or not of the problem and the effectiveness of the solution carried out by the groups. THUNDERS provides assistance for the design of the validation to be done from scratch, following some recommendations, and on the other hand, provides a mechanism already defined to perform such validation.

A mechanism to validate the resolution of the problem

Criterion	Description	Values					
		Very complete = 5 point	Complete = 4 point	Regular = 3 point	Incomplete = 2 point	Very incomplete = 1 point	TOTAL
Problem understanding	Assess whether the relevant information of the problem has been identified: what are the causes, and the effects or consequences, what are the data, the unknowns, and what conditions must be met with the solution.						
Application of the method	Corresponds to the assessment of the procedure. It can be understood as the specific technique that was selected to achieve the solution to the problem.						
Completeness of the developed solution	Corresponds to the completeness assessment of the solution developed by the group and concordance with what was requested in the problem.						
Correctness of the developed solution	Corresponds to the correctness assessment of the solution developed by the group and concordance with what was requested in the problem.						
Justification and clarity	Corresponds to the assessment of the clarity and rigor in the development of the resolution to the problem.						
Results	It corresponds to the evaluation exclusively of the results and the deliverables obtained during the development of the problem resolution.						
Efficiency	If there are several solutions and several ways to reach said solution, the purpose is to evaluate the quality of the chosen solution and the process followed to obtain the solution against the different existing processes.						
Critical analysis	Corresponds to the assessment of the reflections and perceptions made by the participants of the group on the validity of the results obtained.						
Sum of the results obtained in each criterion							

Figure 4.17 Problem-solution validation mechanism

The validation mechanism provided by the task (See Figure 4.17) contains a set of criteria with their description, in Checklist format, to be completed in each group, by the person responsible for this task. For each of the criteria, the corresponding value is selected with an X (between 1 and 5, where 1 is Very incomplete and 5 is Very complete) according to the validation of the solution of the problem, the result obtained, and the process followed, considering each criterion. In the end, the values obtained for each criterion are added up and an interpretation is offered according to the value obtained, determining the solution or not of the problem, its completeness, and correctness.

The task: Design the validation of the shared understanding construction, will allow designing a strategy, the corresponding criteria, and the mechanisms to carry it out, with the objective of determining the achievement or not of the shared understanding (considering the dimensions: individual, group, self-appraisal, individual products, group products), and its correctness. THUNDERS provides assistance for the validation design to be done from scratch, following some recommendations, and on the other hand, it provides a mechanism already defined, for each dimension, to carry out such validation.

The dimension of *individual understanding* refers to the understanding that each participant has before interacting with his group mates, and the one he has after interacting with his mates in the development of the activity and in the resolution of the problem. The purpose of this is to determine whether it coincides with that of others and whether it is correct. The *group understanding* dimension refers to the degree of understanding that the whole group shares or the mutual agreement, after interacting with other peers, about the problem, and the activity to be performed. It also refers to the understanding that the group shares about the solution of the problem and the topics that were acquired by all after performing the activity. *The validation of the products* refers to the analysis of each of the products or deliverables made both individually and as a group, in search of the construction of understanding. And finally, the *self-appraisal* refers to the analysis that each participant makes in a critical and objective way, about their performance to achieve their individual understanding and the contribution and performance to achieve the shared understanding in the group during the development of the collaborative activity.

A mechanism to validate the individual understanding construction

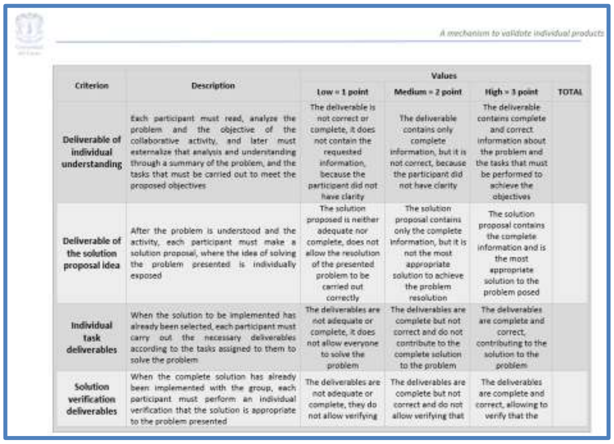
Criterion	Description	Values			
		Low = 1 point	Medium = 2 point	High = 3 point	TOTAL
Understanding	It is the faculty that the participant must have to relate and reason the concepts and definitions of the problem and the activity objective, through reasoning carried out, to comprise the needs, its essential root, and the details that compose it	The participant did not correctly understand the problem established to be solved and the activity objective	The participant's understanding is moderately correct about the problem posed and the activity objective	The participant's understanding is correct about the problem posed and the activity objective	
Understanding of individual tasks to implement the solution	It is the faculty that the participant must have to relate and reason the concepts and definitions necessary on the individual tasks that were assigned to implement the solution of the problem	The participant did not correctly understand the individual tasks assigned to him to implement the solution	The participant's understanding is moderately correct about the individual tasks assigned to him to implement the solution	The participant's understanding is correct about the individual tasks assigned to him to implement the solution	
Understanding of the implemented solution	It is the faculty that the participant must have to relate and reason the necessary concepts and definitions about the implemented solution to understand its essential root and the details that compose it	The participant did not understand the solution implementation correctly	Participant understanding is moderately correct about the solution implementation	The participant's understanding is correct about the solution implementation	
Search material to understand	The participant's ability to search for strategies and material other than that provided to understand the information, concepts, and topics used during the collaborative activity	The participant does not worry about understanding through material or strategies	The participant limits himself to using the delivered material to understand	The participant searches for strategies and additional material to understand	
Ease of understanding	Refers to the ease with which a participant understands the topics that are handled during the development of the activity and during the resolution of the problem	It is difficult for the participant to understand new concepts and definitions, he/she	The participant does not have the facility to understand new concepts and definitions, but	The participant has the facility for the understanding of new concepts and definitions	

Figure 4.18 Validate individual understanding

A mechanism to validate the group understanding constructio

Criterion	Description	Values			
		Low = 1 point	Medium = 2 point	High = 3 point	TOTAL
The shared understanding of problem and activity	It is the faculty that the group must have to relate and reason the concepts and definitions of the problem and the activity objective, through the analysis carried out, to understand the needs, its essential root and the details that compose it	The group did not correctly understand the problem to be solved and the activity objective	The group's understanding is moderately correct about the problem posed and the activity objective	The group's understanding is correct about the problem posed and the activity objective	
Understanding of the implemented solution	It is the faculty that the group must have to relate and reason the necessary concepts and definitions about the implemented solution to understand its essential root and the details that compose it	The group did not correctly understand the implementation of the solution	The group's understanding is moderately correct on the implementation of the solution	The group's understanding is correct about the implementation of the solution	
Search material to understand as a group	The group's ability to search for strategies and material other than that provided so that all group members can understand the information, concepts, and topics used during the collaboration activity	The group does not worry about understanding through additional material or strategies	The group limits itself to using the delivered material to understand	The group searches for strategies and additional material to understand	
Group clarification questions	By sharing understandings, analyzing the problem and the activity, sharing the solutions to be implemented, implementing the solution, and verifying the resolution of the problem, the group may have doubts, concerns, or questions that cannot be resolved among the group members, therefore, it must be determined if these concerns made to the activity leader are necessary and sufficient to clarify the understanding of the group	The group does not generate doubts, concerns, or questions, which does not allow you to improve the group understanding	The doubts, concerns, or questions that the group has are not necessary and sufficient to clarify the group understanding	The doubts, concerns, or questions that the group asks are necessary and sufficient to clarify the group understanding	

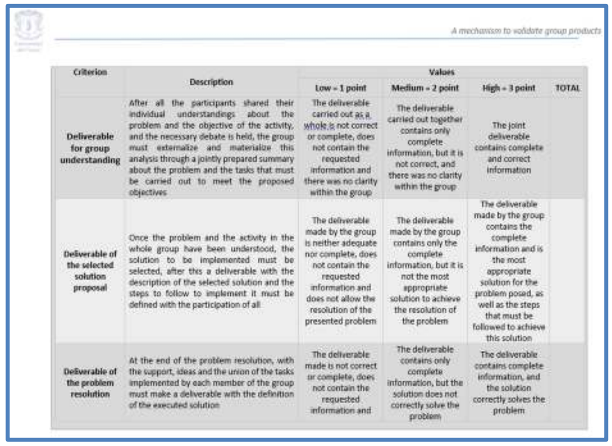
Figure 4.19 Validate group understanding



A mechanism to validate individual products

Criterion	Description	Values			
		Low = 1 point	Medium = 2 point	High = 3 point	TOTAL
Deliverable of individual understanding	Each participant must read, analyze the problem and the objective of the collaborative activity, and later must externalize that analysis and understanding through a summary of the problem, and the tasks that must be carried out to meet the proposed objectives	The deliverable is not correct or complete, it does not contain the requested information, because the participant did not have clarity	The deliverable contains only complete information, but it is not correct, because the participant did not have clarity	The deliverable contains complete and correct information about the problem and the tasks that must be performed to achieve the objectives	
Deliverable of the solution proposal idea	After the problem is understood and the activity, each participant must make a solution proposal, where the idea of solving the problem presented is individually exposed	The solution proposed is neither adequate nor complete, does not allow the resolution of the presented problem to be carried out correctly	The solution proposal contains only the complete information, but it is not the most appropriate solution to achieve the problem resolution	The solution proposal contains the complete information and is the most appropriate solution to the problem posed	
Individual task deliverables	When the solution to be implemented has already been selected, each participant must carry out the necessary deliverables according to the tasks assigned to them to solve the problem	The deliverables are not adequate or complete, it does not allow everyone to solve the problem	The deliverables are complete but not correct and do not contribute to the complete solution to the problem	The deliverables are complete and correct, contributing to the solution to the problem	
Solution verification deliverables	When the complete solution has already been implemented with the group, each participant must perform an individual verification that the solution is appropriate to the problem presented	The deliverables are not adequate or complete, they do not allow verifying	The deliverables are complete but not correct and do not allow verifying that	The deliverables are complete and correct, allowing to verify that the	

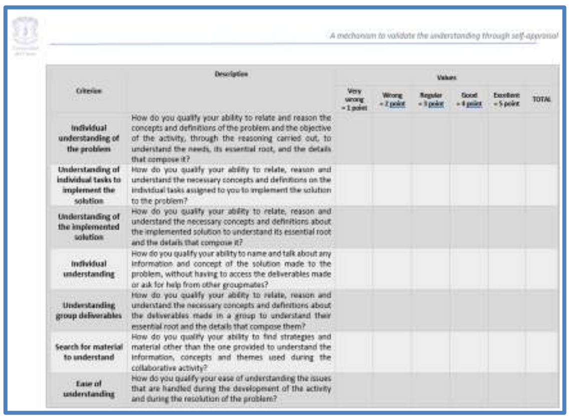
Figure 4.20 Validate individual results



A mechanism to validate group products

Criterion	Description	Values			
		Low = 1 point	Medium = 2 point	High = 3 point	TOTAL
Deliverable for group understanding	After all the participants shared their individual understandings about the problem and the objective of the activity, and the necessary debate is held, the group must externalize and materialize this analysis through a jointly prepared summary about the problem and the tasks that must be carried out to meet the proposed objectives	The deliverable carried out as a whole is not correct or complete, does not contain the requested information and there was no clarity within the group	The deliverable carried out together contains only complete information, but it is not correct, and there was no clarity within the group	The joint deliverable contains complete and correct information	
Deliverable of the selected solution proposal	Once the problem and the activity in the whole group have been understood, the solution to be implemented must be selected, after this a deliverable with the description of the selected solution and the steps to follow to implement it must be defined with the participation of all	The deliverable made by the group is neither adequate nor complete, does not contain the requested information and does not allow the resolution of the presented problem	The deliverable made by the group contains only the complete information, but it is not the most appropriate solution to achieve the resolution of the problem	The deliverable made by the group contains the complete information and is the most appropriate solution for the problem posed, as well as the steps that must be followed to achieve this solution	
Deliverable of the problem resolution	At the end of the problem resolution, with the support, ideas and the union of the tasks implemented by each member of the group must make a deliverable with the definition of the executed solution	The deliverable made is not correct or complete, does not contain the requested information and	The deliverable contains only complete information, but the solution does not correctly solve the problem	The deliverable contains complete information, and the solution correctly solves the problem	

Figure 4.21 Validate group results



A mechanism to validate the understanding through self-appraisal

Criterion	Description	Values					
		Very wrong = 1 point	Wrong = 2 point	Regular = 3 point	Good = 4 point	Excellent = 5 point	TOTAL
Individual understanding of the problem	How do you qualify your ability to relate and reason the concepts and definitions of the problem and the objective of the activity, through the reasoning carried out, to understand the needs, its essential root, and the details that compose it?						
Understanding of individual tasks to implement the solution	How do you qualify your ability to relate, reason and understand the necessary concepts and definitions on the individual tasks assigned to you to implement the solution to the problem?						
Understanding of the implemented solution	How do you qualify your ability to relate, reason and understand the necessary concepts and definitions about the implemented solution to understand its essential root and the details that compose it?						
Individual understanding	How do you qualify your ability to name and talk about any information and concept of the solution made to the problem, without having to access the deliverables made or ask for help from other groupmates?						
Understanding group deliverables	How do you qualify your ability to relate, reason and understand the necessary concepts and definitions about the deliverables made in a group to understand their essential root and the details that compose them?						
Search for material to understand	How do you qualify your ability to find strategies and material other than the one provided to understand the information, concepts and themes used during the collaborative activity?						
Ease of understanding	How do you qualify your ease of understanding the issues that are handled during the development of the activity and during the resolution of the problem?						

Figure 4.22 Validate self-appraisal

For the validation in each of the dimensions (See **¡Error! No se encuentra el origen de la referencia.**, **¡Error! No se encuentra el origen de la referencia.**, Figure 4.20, Figure 4.21 and Figure 4.22), the task provides mechanisms that contain a set of criteria with their description , in Checklist format, to be filled in by the person responsible for the validation. For each of the criteria, the corresponding value is selected with an X (between 1 and 3, being 1 Low and 3 High). For the self-appraisal Checklist, the range of values is from 1 to 5, 1 Very bad and 5 Excellent) according to the validation of the observed and the results considering each criterion. At the end, the values obtained for each criterion are added up and an interpretation is offered according to the value obtained in each dimension, to determine the complete and correct construction of the shared understanding.

In addition to these mechanisms shown above, THUNDERS provides a mechanism to validate the construction of shared understanding through the creation and comparison of concept maps (See Figure 4.23), considering in this mechanism both individual and group dimension. To this end, individual concept maps are created to represent the mental map of each individual. In order to then be able to analyze to what extent one map coincides with another, in addition to defining whether each map is correctly constructed. A concept map is a visual representation to give a synopsis on a specific topic, which allows to organize and understand the ideas in a meaningful way according to a selected topic, where concepts are analyzed, and special attention is paid to the relationship and interconnection between them.

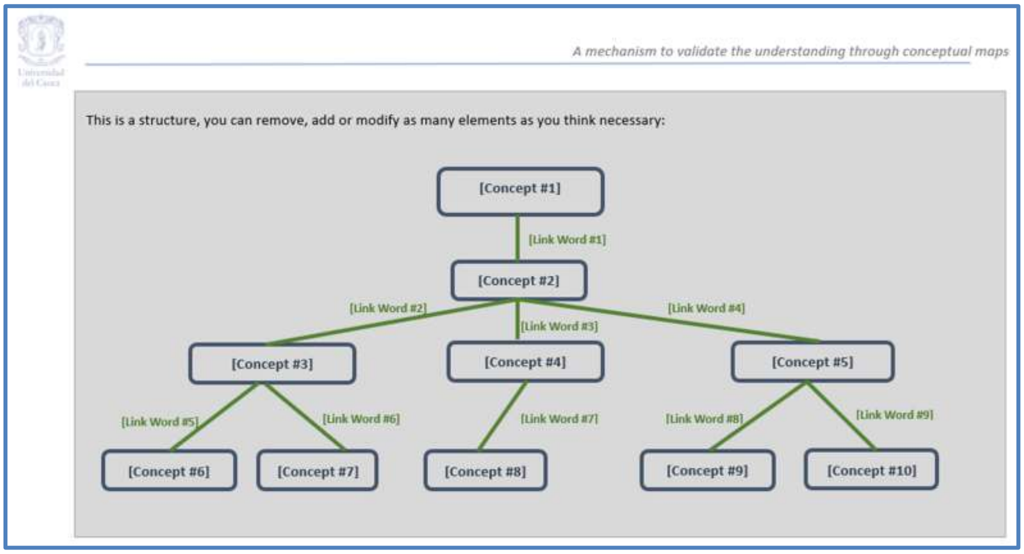


Figure 4.23 Validation through concept maps

For this purpose, the specification of the mechanism contains:

- Considerations for when to choose this mechanism
- Considerations for when not to choose this mechanism
- Explanation of the elements that will be contained in the concept map
- The steps for the construction of individual concept maps
- An example of a concept map
- Formats for executing each step of concept map construction
- Steps for comparing individual concept maps
- Formats for comparing the maps
- The ranges of values allow the interpretation of the values obtained for each group, determining the correct and complete construction of the shared understanding

The task: Design the evaluation of the participants' performance, will make it possible to design a strategy, the corresponding criteria, and the mechanisms to carry it out, with the objective of analyzing the participants' performance (considering the individual, group, and self-appraisal dimensions). Performance is divided into two aspects: results and behaviors, i.e., "what" the participant and the group do (i.e., the results they achieve), and behaviors are "how" they produce those results. In addition to analyzing dedication, discipline, participation, collaboration, social aspects, and self-appraisal, as well as the presence of values and skills. For this evaluation, THUNDERS provides assistance for the design of the evaluation to be done from scratch, following recommendations, and on the other hand, it provides a mechanism already defined, for each dimension, to carry out this evaluation.

A mechanism to evaluate the individual performance

Criterion	Description	Values					
		Very wrong = 1 point	Wrong = 2 point	Regular = 3 point	Good = 4 point	Excellent = 5 point	TOTAL
Participation aspect							
Action to participate	It is the ability of each member of the group to intervene during the activity development						
Quality of participation	It refers to the evaluation and/or satisfaction of the intervention carried out by the participant						
Contribution of ideas	It refers to clear, well-structured and consistent ideas, which are contributed during the exchange of information that takes place between the group participants						
Interaction	It refers to the ability of the participant to interact, relate and respond to other participants in the moments that are required						
Complete tasks	It refers to the ability of the participant to complete a task or parts of it individually						
Vocabulary used	It refers to the participant's ability to use new words during the exchange of ideas and the unknown words define them correctly						
Fulfillment of time	It refers to the participant's ability to correctly and adequately use the time allotted to participate						
Respect his turn	It refers to the ability of the participant to respect the rules for assigning turns, asking to speak when necessary and participating when it corresponds						
Enrich the participation of others	It refers to the participant's ability to intervene, complementing, enriching, improving, and commenting on the participation of the other groupmates						
Concern about the participation of	It refers to the participant's ability to promote and encourage the participation of other group mates						

Figure 4.24 Evaluate individual performance

A mechanism to evaluate the group performance

Criterion	Description	Values					
		Very wrong = 1 point	Wrong = 2 point	Regular = 3 point	Good = 4 point	Excellent = 5 point	TOTAL
Group composition	It refers to the composition of the group in terms of size and degree of heterogeneity, determining if it is adequate to carry out the activity and solve the problem						
Participation	It refers, in general, to the attention and interest that the members of the group present to participate in the different activities carried out through listening and socializing their ideas						
Group decisions	It refers to the way in which groups make decisions democratically, considering the opinions of other groupmates						
Time management	It refers to the time management carried out by the group during the development of the activity to ensure that deliveries are made correctly according to the agreed time						
Group organization	It refers to how the groups are distributed and organized to correctly solve the problem and fulfill all the proposed and assigned activities						
Group responsibility	It refers to how the groups have strategies so that individual and group responsibilities are fulfilled to achieve the resolution of the problem						
Group results	It refers to the results obtained by the group during the development of the collaborative activity in each of its activities, tasks, and other elements that allowed solving the problem						
Use of the material	It refers to the ability of the group to use the material delivered to solve the problem as requested and to look for additional material that helps the correct development of the activity						

Figure 4.25 Evaluate group performance

A mechanism to evaluate the participants performance through self-appraisal

Criterion	Description	Values					
		Very wrong = 1 point	Wrong = 2 point	Regular = 3 point	Good = 4 point	Excellent = 5 point	TOTAL
Participation							
Action to participate	How do you qualify your ability to intervene during the development of the activity?						
Quality of participation	How do you qualify the quality of your interventions made during the development of the collaborative activity?						
Contribution of ideas	How do you qualify the clarity, structure and consistency of the ideas that you contribute during the exchange of information that takes place among your fellow group members?						
Interaction	How do you qualify your ability to interact, relate and respond to your other groupmates in the moments that are required?						
Complete tasks	How do you qualify your ability to complete a task or parts of it during the development of the collaborative activity?						
Vocabulary used	How do you qualify your ability to use new words during the exchange of ideas and do you correctly define unfamiliar words when you interact with your mates?						
Fulfillment of time	How do you qualify your correct and adequate use of the time that you have been allocated to participate in the exchange of ideas?						
Respect your turn	How do you qualify your ability to abide by the shift allocation rules, asking to speak when necessary and participating when appropriate?						
Enrich the participation of others	How do you qualify your ability to intervene, complementing, enriching, improving and commenting on the participation of your other groupmates?						

Figure 4.26 Evaluate performance through self-appraisal

For the evaluation in each of the dimensions, the task provides mechanisms that contain a set of criteria with their description (See Figure 4.24, Figure 4.25 and Figure 4.26), in Checklist format, to be filled in by the person responsible for the evaluation. For each of the criteria, the corresponding value is selected with an X (between 1 and 5, being 1 Very incorrect and 5 Excellent) according to the evaluation of what was observed and the results considering each criterion. In the end, the values obtained for each criterion are added up and an interpretation of the value obtained in each dimension is given to determine the performance of the participants and the group.

The task: Design the feedback strategy and mechanisms, will allow designing the strategy (when and how it will be done) and the necessary mechanisms to provide feedback on the results obtained in the validations, and the evaluation carried out, in order to look for improvement strategies in future activities in which they participate. The task provides as assistance, a document of recommendations for the design of the strategy, mechanisms, and information to be delivered during the feedback.

The following Table 4.11 shows the summary of the names of the tasks, roles, inputs, outputs, and assistance documents used in this activity.

Task	Roles	Inputs	Outputs	Work products
Design the validation of the compliance with the problem	Instrument designer	Problem and its information (Filled out)	Plan to validate the resolution of the problem (Filled out)	A mechanism to validate the resolution of the problem
		Activity description and its information (Filled out)		
	Activity designer	Definition of types of objectives (Filled out)		
	Activity coordinator	Success criteria description (Filled out)		
		Plan to validate the resolution of the problem	Validate the resolution of the problem	
Design the validation of the shared understanding construction	Instrument designer	The detailed specification of the collaborative activity (Filled out)	Plan to validate the shared understanding construction (Filled out)	Recommendations to validate the shared understanding construction
				A mechanism to validate the individual understanding construction
				A mechanism to validate the group understanding construction
		Design and assignment of roles (Filled out)		A mechanism to validate the understanding through self-appraisal
	Activity designer		Validate the shared understanding construction	A mechanism to validate the understanding through conceptual maps
	Activity coordinator	Plan to validate the shared understanding construction		A mechanism to validate individual products
				A mechanism to validate group products
Design the evaluation of the participants' performance	Instrument designer	The detailed specification of the collaborative activity (Filled out)	Plan to evaluate the participants' performance (Filled out)	Recommendations to evaluate the participants' performance
		Definition of types of objectives (Filled out)		A mechanism to evaluate the individual performance
	Activity designer	Success criteria description (Filled out)		A mechanism to evaluate the group performance
		Activity rules description (Filled out)	Evaluate the participants' performance	
		Design and assignment of roles (Filled out)		A mechanism to evaluate the participants' performance through self-appraisal
	Activity coordinator	Plan to evaluate the participants' performance		
Design the feedback strategy and mechanisms	Instrument designer	Activity description and its information (Filled out)	Strategy to give feedback (Filled out)	Recommendations to design the feedback strategy and mechanisms
		Plan to validate the resolution of the problem (Filled out)		
	Activity designer	Plan to validate the shared understanding construction (Filled out)		
		Plan to evaluate the participants' performance (Filled out)	Mechanisms to give feedback	
	Activity coordinator	Strategy to give feedback		
Monitor the tasks to design the validation and	Activity coordinator	Monitor the design of the problem compliance validation	Monitor the design of the problem compliance validation (Filled out)	--

evaluation methods	Activity leader	Monitor the design of the validation of the shared understanding construction.	Monitor the design of the validation of the shared understanding construction (Filled out)	
	Instrument designer	Monitor the design of participant performance evaluation	Monitor the design of participant performance evaluation (Filled out)	
	Activity designer	Monitor the design of feedback mechanisms and strategies	Monitor the design of feedback mechanisms and strategies (Filled out)	

Table 4.11 Elements of the activity "Design the validation and evaluation methods"

4.5.2 Beginning phase roles

As previously mentioned, in this chapter only the Beginning phase will be shown in detail, considering that it is necessary to design a collaborative activity with each of its elements in order to subsequently execute what has been established in the following phases. In addition to the elements shown, each phase contains primary and secondary roles, which are responsible for executing the THUNDERS tasks and their respective work products, where each role has its description and necessary skills. Here is specifically shown the primary role for each task of the Beginning phase, and *Annex 6* is shown the information corresponding to each role and their information of the other phases.

In this sense, the *Instrument Designer* (See the tasks in charge Figure 4.27**¡Error! No se encuentra el origen de la referencia.** is responsible for identifying and defining the responsibilities, attributes, elements, and relationships of the different instruments to be designed, ensuring that the design is consistent with the needs and their respective details. The *Activity Coordinator* (See Figure 4.28) is responsible for managing, monitoring, and coordinating the inputs, activities, tasks, and steps of the process so that they are carried out within the stipulated time and design. He/she is also in charge of analyzing the information obtained in the process in order to make the pertinent decisions required.

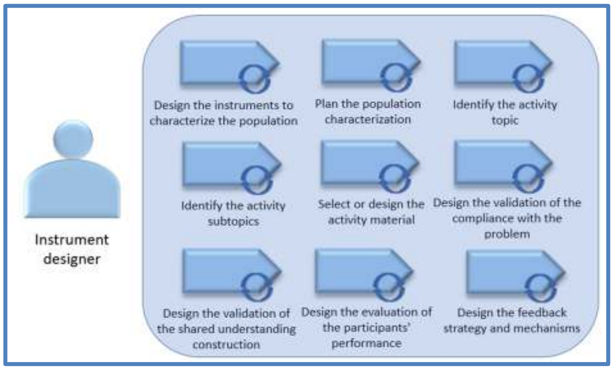


Figure 4.27 Tasks assigned to the Instrument designer role

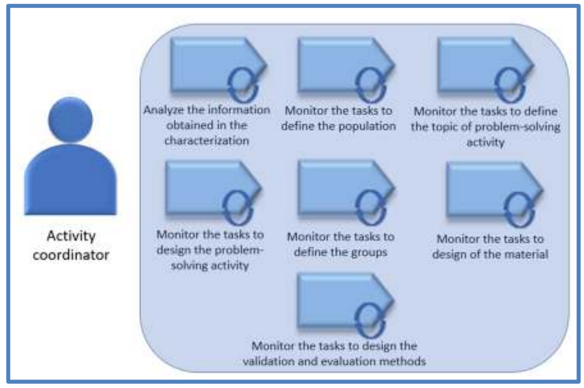


Figure 4.28 Tasks assigned to the Activity coordinator role

The *Activity Designer* (See Figure 4.29) is responsible for defining the outline and details of the collaborative activity, identifying, and defining the elements, responsibilities, attributes, and relationships that must be executed in the collaborative activity to meet the objectives and solve the problem. This role must also ensure that the design is consistent with the participants, the problem, and the issues chosen for subsequent implementation. The *Information Collector* (See Figure 4.30) is responsible for managing and carrying out the process of collecting important and necessary information within the process tasks, managing the appropriate use of the instruments designed for this purpose, and ensuring the quality of the information collected.

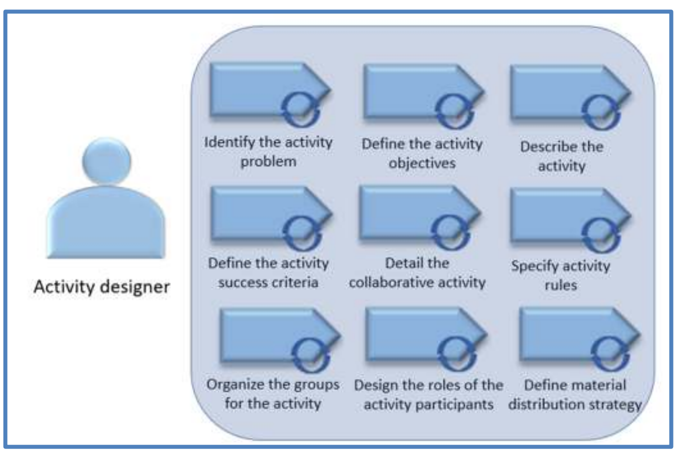


Figure 4.29 Tasks assigned to the Activity designer role

Figure 4.30 Tasks assigned to the Information collector role

4.6 THUNDERS publication

As mentioned above, EPFC has been used to specify through SPEM 2.0 the THUNDERS process, where a process is obtained with each of its elements, phases, activities, tasks, workflows, and associated work products. In this sense, THUNDERS has been published in web format, to facilitate its navigation and to have all its information condensed. This publication can be accessed at the following link:

https://pakhzwh6odwabqquybb4qw.on.drv.tw/hosting/index.htm

When entering the Link where the process is specified, a description of THUNDERS is shown with each of its elements, in addition to presenting the flowchart of each of the phases that are part of it (See Figure 4.31).

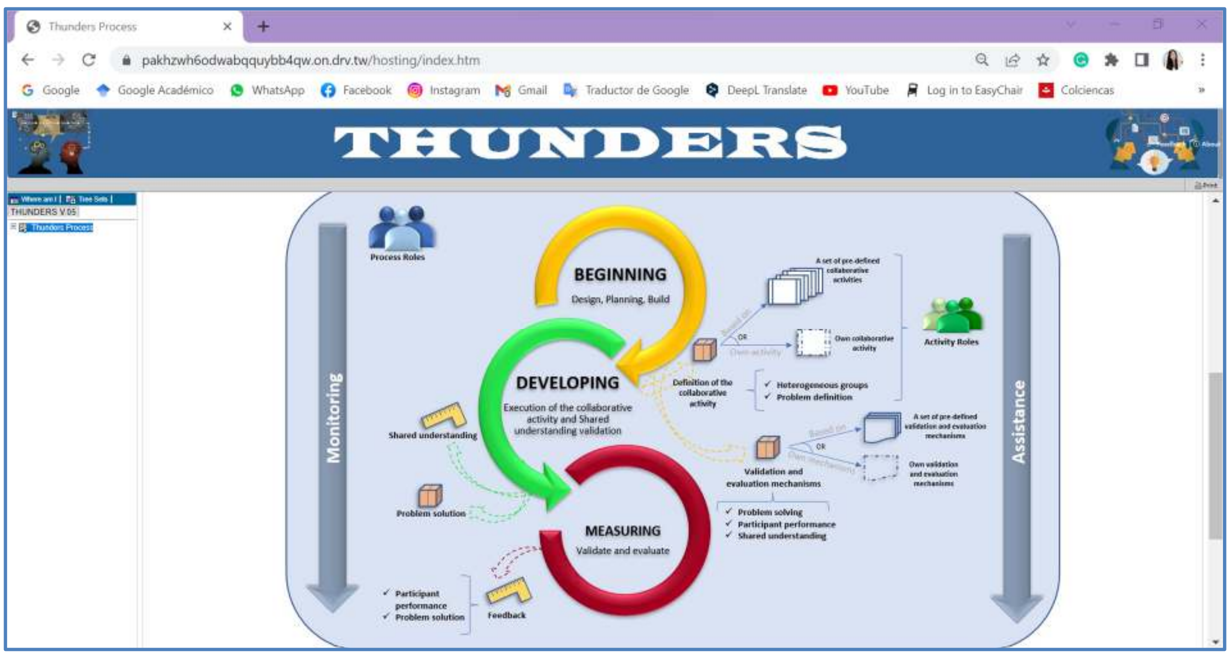


Figure 4.31 THUNDERS Description

The website allows access to the flowchart of each activity (See Figure 4.32), and by clicking on each activity can access the task flowchart (See Figure 4.33) and accessing each task can see the elements of the selected task, with each of its elements (See Figure 4.34), and access to the corresponding assistance documents (See Figure 4.35).

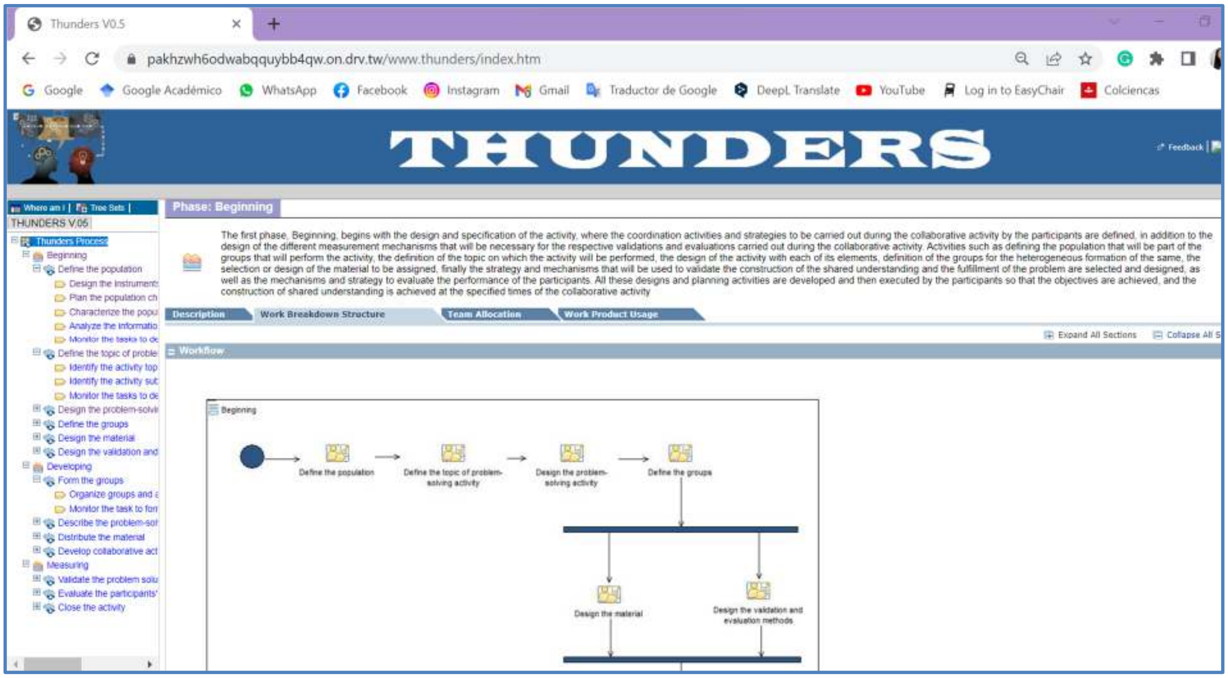


Figure 4.32 Flowchart of each activity

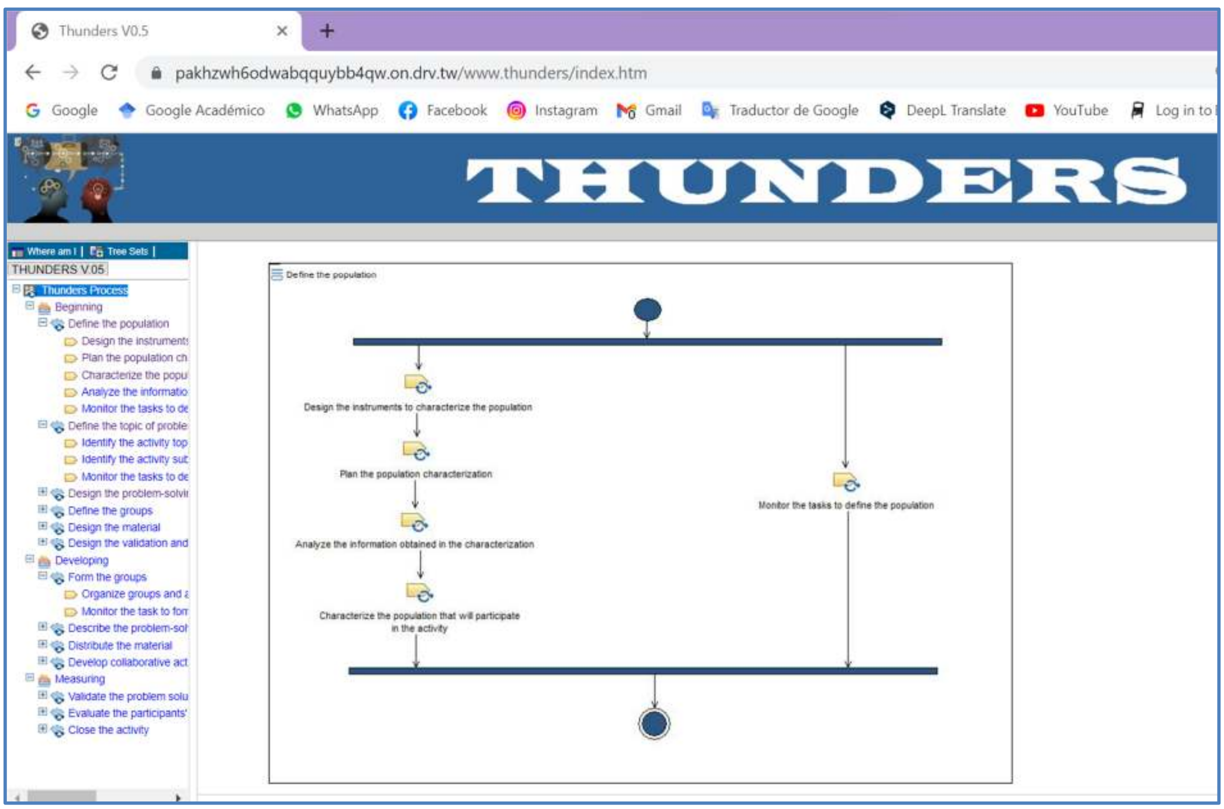


Figure 4.33 Flowchart of each task

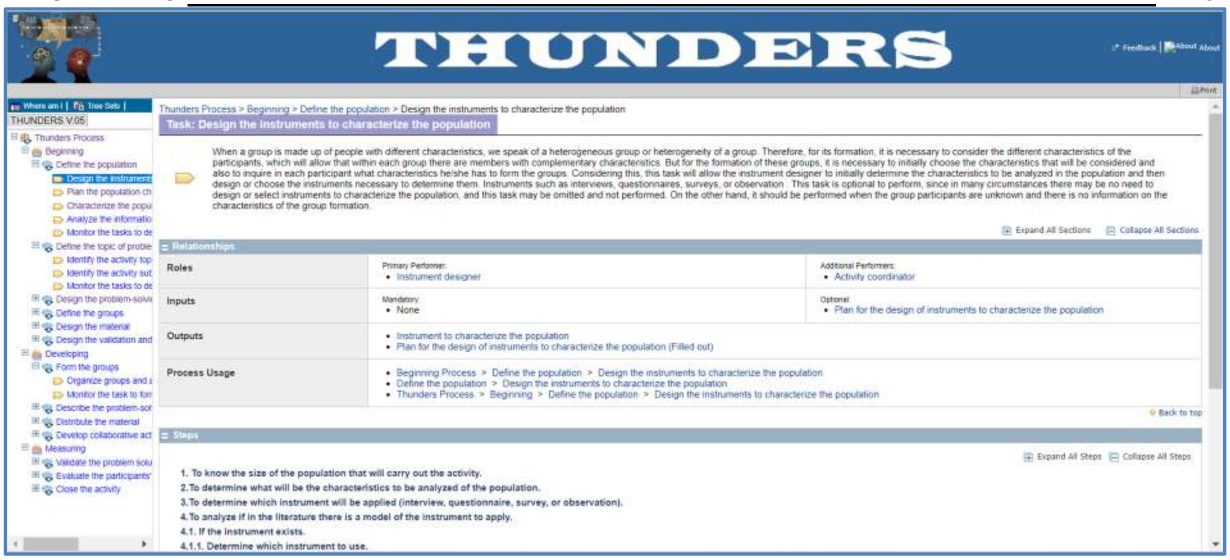


Figure 4.34 Elements of the selected task

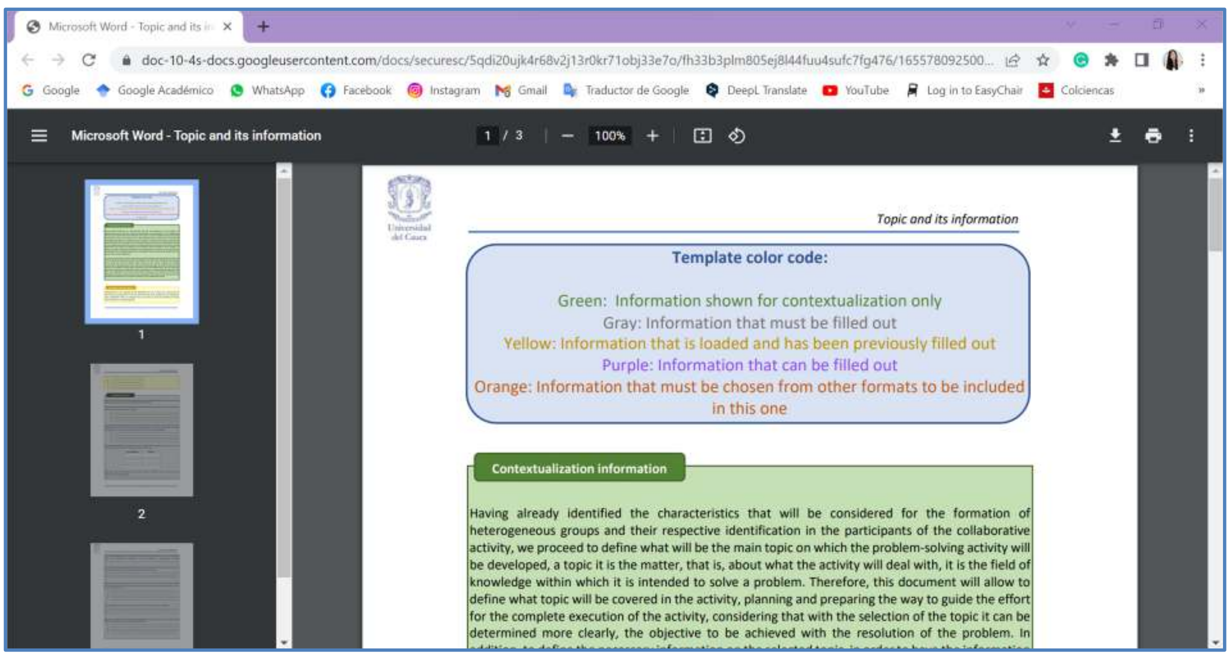


Figure 4.35 Assistance document of the task

Chapter 5

THUNDERS PROCESS VALIDATION

5.1 Overview

In proposing the THUNDERS process to improve collaborative work through the construction, monitoring, and assistance of shared understanding, iterations were considered that allowed the iterative and incremental construction of the process specification, and several validations of each of its versions, which considered direct aspects and different contexts. For this reason, this chapter shows each of the validations carried out in the five iterations obtained from the process, with the design, execution, and analysis of the results obtained from each validation. With the first version of the process, a first validation was performed through an experiment that allowed analyzing if this version was feasible and useful, in addition, an exploratory study was performed where it was analyzed if this version promoted and improved the shared understanding. With a second version, an expert validation was performed to analyze the structure of the process according to SPEM 2.0, analyzing its syntax and semantics. With a third version of the process called THUNDERS, an experiment was conducted in a requirements engineering context to determine the completeness, usefulness, and ease of use of the process. With a fourth version, validation was performed with collaborative experts to determine if the elements were clear and complete and to determine those tasks that were mandatory or not to be performed. Finally, with a fifth version of the process, a case study was conducted to determine whether the process in its latest version improves collaborative work. The sections of this chapter are summarized in the following image (See Figure 5.1).

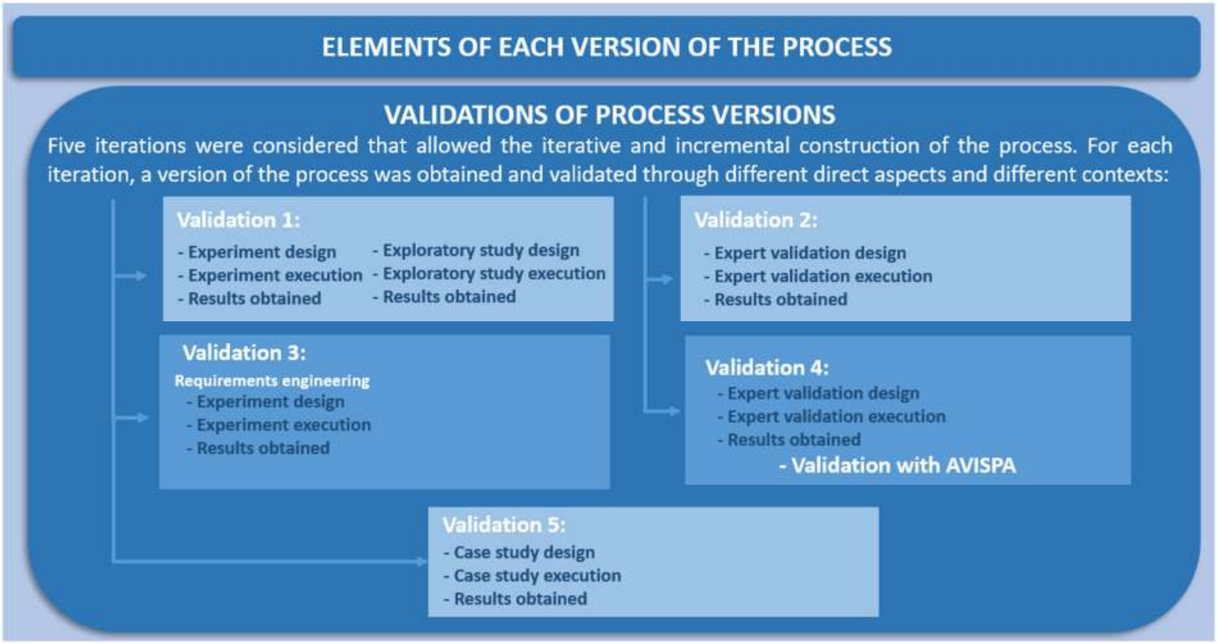


Figure 5.1 Sections presented in this chapter

5.2 Elements of each version of the process

As previously mentioned, the process, in order to reach its final version, had several versions that were built as results were obtained and needs were identified in each of the validations carried out. In this sense, the following Figure 5.2 summarizes the main elements of the five versions of the process, which were validated in each iteration, and will be explained in the sections that follow.

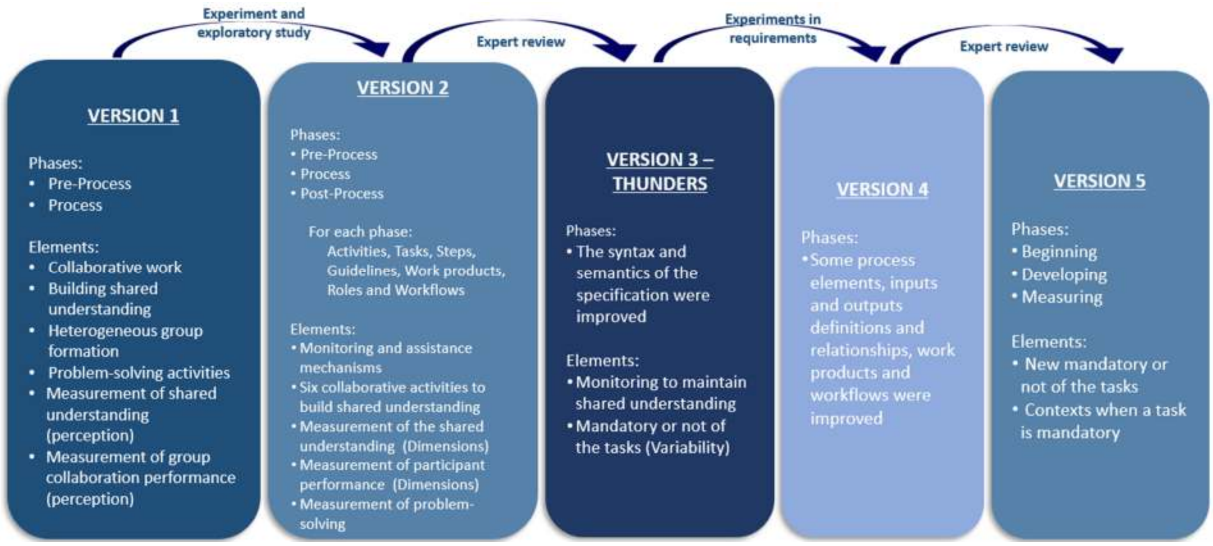


Figure 5.2 Elements of each version

5.3 Validations of process versions

A validation process constitutes one of the main quality requirements to be fulfilled to guarantee the satisfaction of the context needs, specifically as shown in Chapter 3, the improvement opportunities, and the identified requirements. Each of the validations performed to the versions of the process are detailed below, through documented evidence that provides a degree of assurance that the application of the specified process produces results and products meeting the specifications and predetermined quality characteristics in the Beginning phase.

5.3.1 Validation 1 - Experiment

The following experiment was intended to validate the feasibility and usefulness of the first version of the process, which defined two phases Pre-Process focused on designing the collaborative problem-solving activity, with heterogeneous group formation; and the Process phase focused on executing the activity and building shared understanding, measuring this construction after seeking to understand what each group had to do to solve the activity, through perception, in addition to measuring the performance of collaboration among participants at the end of the activity. The following sections show in detail what was done to analyze the results of this experiment.

5.3.1.1 Experiment design

<u>Context and objective of the experiment</u>

The experiment was conducted in a university environment considering two scenarios: 45 students from the Universidad de la Matanza - UM (Argentina), who applied the proposed process, and on the other hand, 15 students from the Universidad Nacional de la Plata - UP (Argentina), who served as contrast groups where the process was not applied. For the formation of the groups, the characteristic of learning styles was selected. With this, the groups were formed using a software tool called Collab (Lescano & Costaguta, 2018) that analyzes learning styles and organizes the group heterogeneously using a genetic algorithm described in (Lescano, Costaguta, & Amandi, 2016). To identify the predominant style of each participant, each participant filled out a questionnaire, and subsequently, based on these results, Collab formed groups of 5 students heterogeneously. On the other hand, the problem-solving activity, consisted of each group assuming that they were part of the process engineering group of a software development company, where they had to establish the development processes that best adapted and supported the company's projects, thus defining the scope of a process line. Each group had to follow an execution guide called SpeTion-SPrl, following a set of templates and formats that they had to develop collaboratively, to solve the problem of the activity, which was mainly to define the scope of a software process line so that it could adapt and support the projects that the company currently managed.

The objective of the experiment was to inquire about the feasibility and usefulness of the proposed process for the construction of shared understanding in a problem-solving activity. For this purpose, the following research question was posed: *How feasible and useful is the proposed process?*

Experiment hypothesis

Considering the objective of the experiment, the following hypotheses were evaluated:

- The proposed process is feasible for the construction of shared understanding in a problem-solving activity.
- The proposed process is useful for achieving the objectives of a problem-solving activity.

In Table 5.1, to refine the above hypotheses, the following specific hypotheses and their respective variables were raised:

Specific hypotheses		Variables
Feasibility	H.1.1. Improvement in the participants' descriptions about what they should do	*1.1.a Improvement in the group descriptions:* it represents the statistically significant difference between the grades of individual and group descriptions.
		1.1.b Improvement in the UM and UP descriptions: it represents the statistically significant difference in the grades given to the group descriptions between UM and UP groups.
	H.1.2. The participants understand and agree on the	*1.2.a Understanding other descriptions*: it represents a participant's perceptual judgment on understanding other descriptions.

	descriptions from their other groupmates of what should be done	*1.2.b The opinion of other descriptions*: it represents a participant's perceptual judgment on the opinion of other descriptions.
	H.1.3. Improvement in the homogeneous understanding and the discrepancy between each participant with others, about what they should do	*1.3.a Improvement in the homogeneous understanding*: it represents the statistically significant difference between the perceptual judgment of the homogeneous understanding before and after the use of the process.
		1.3.b Improvement in the discrepancy: it represents the statistically significant difference between the perceptual judgment of the discrepancy before and after the use of the process.
		1.3.c Improvement in the homogeneous understanding in UM and UP: it represents the statistically significant difference of the perceptual judgment of the homogeneous understanding between the UM and UP groups.
		1.3.d Improvement in the discrepancy in UM and UP: it represents the statistically significant difference of the perceptual judgment of the discrepancy between the UM and UP groups.
	H.1.4. Improvement in the activity results of the Shared Understanding stage	*1.4.a Improvement in the Construction activity*: it represents the statistically significant difference of the perceptual judgment of the Construction activity results between the UM and UP groups.
		1.4.b Improvement in the Co-Construction activity: it represents the statistically significant difference of the perceptual judgment of the Co-Construction activity results between the UM and UP groups.
		1.4.c Improvement in the Constructive conflict activity: it represents the statistically significant difference of the perceptual judgment of the Constructive conflict activity results between the UM and UP groups.
Utility	H.2.1. Improves in the quality of the final obtained results when performing the problem-solving activity.	*2.1 Improvement in the quality of the results*: it represents the statistically significant difference of the grades given to the final results of the activity between the UM and UP groups.
	H.2.2. The number of posed questions to the activity coordinator decreases	*2.2 Improvement in the number of questions*: it represents the statistically significant difference in the number of posed questions to the activity coordinator between the UM and UP groups.
	H.2.3. Improves the perception of the participants' satisfaction, about the achievement of the activity objectives	*2.3 Improvement in the perception about the objective achievement*: it represents the statistically significant difference in the perceptual judgment on the perception in the objective achievement between the UM and UP groups.
	H.2.4. The use of the process improves the perception of the participants' satisfaction with the process elements and with the activity outcome.	*2.4.a Improvement in the perception about the satisfaction with the process elements:* it represents the statistically significant difference in the perceptual judgment of the satisfaction with the process elements between the UM and UP groups.
		2.4.b Improvement in the perception about the satisfaction with the activity outcome: it represents the statistically significant difference in the perceptual judgment of the satisfaction with the activity outcome between the UM and UP groups.

Table 5.1 Specific hypotheses with their respective variables

<u>Design of experiment activities</u>

In order to execute the experiment, a set of activities were designed, which allowed carrying out all the necessary actions to obtain the expected results. These activities, with their expected duration and the instruments used, are presented in the following Table 5.2.

Experiment activity	Planned duration	Support instruments
Activity 1: Execution of the Pre-Process Phase (Only by the UM)	1 hour	Previously, a computer tool MEPAC (Agredo, Ruiz, Collazos, & Fardoun, 2017) was developed internally, which through forms, provided the step-by-step for the design and definition of the necessary elements for the execution of each activity of the Pre-Process.
Activity 2: Socialize and contextualize the experiment	20 minutes	Presentation of the introduction to the experiment and conceptual elements.
Break	5 minutes	None.
Activity 3: Formation of the groups (Only by UM)	5 minutes	For the conformation of the heterogeneous groups, the Collab tool (Lescano & Costaguta, 2018) was selected.

Activity 4: Presentation and reading of the activity to be carried out	5 minutes	Activity document and results templates.
Activity 5: Individual comprehension and writing of questions (Only by UM)	15 minutes	Format for each participant to write a description of what they understood from the activity, and format to write their questions.
Activity 6: Reading individual comprehensions and writing questions (Only by UM)	10 minutes	Format for each participant to write their questions about the descriptions of the other participants' understanding.
Activity 7: Questions to classify other descriptions (Only by UM)	5 minutes	Format for each participant to rank from 1 to 5 (1 unclear and disagree, 5 very clear and agree) the clarity and opinion they have according to each of their peers' descriptions of understanding (Scale taken from (Bittner & Leimeister, 2014)).
Activity 8: Pre-understanding form	5 minutes	Format for each participant to determine whether, in their judgment, there are shared understandings and/or knowledge differences with their group mates (Questions taken from (Bittner & Leimeister, 2014).
Activity 9: Conflict Resolution and group questions (Only by UM)	10 minutes	None.
Activity 10: Group understanding	10 minutes	Format for each group to write together a description of what they understood about the activity to be performed.
Activity 11: Post-understanding form	5 minutes	The format used in activity 8 is filled out again.
Activity 12: Collaborative activity execution	60 minutes	Templates to be filled to solve the problem.
Activity 13: Survey	10 minutes	Survey format for each participant to answer 4 sections of questions, according to their criteria, about the behavior of the group when working collaboratively, about the achievement of the objectives within the group, about the satisfaction with the elements of the proposed process, and finally, about the satisfaction with the results obtained from the activity (Questions taken from (Van den Bossche, Gijselaers, Segers, Woltjer, & Kirschner, 2011)).
		TOTAL TIME: 3 hours 45 minutes

Table 5.2 Design of experiment activities

5.3.1.2 Experiment execution

The UM groups applied all the activities, tasks, and steps specified in the process, making use of the tools provided for their support, both for the Pre-Process and Process phases. For their part, the UP groups carried out the same collaborative activity designed, with the formation of random groups, and simply among the groups, they provided a solution to the activity without following the proposed process. Table 5.3 shows the time invested in each of the activities by the UM and UP groups.

Activities	UM	UP	Estimated time
Activity 1	40 minutes	--	1 hour
Activity 2	20 minutes	25 minutes	20 minutes
Break	5 minutes	5 minutes	5 minutes
Activity 3	10 minutes	--	5 minutes
Activity 4	5 minutes	5 minutes	5 minutes
Activity 5	10 minutes	--	15 minutes
Activity 6	5 minutes	--	10 minutes
Activity 7	3 minutes	--	5 minutes
Activity 8	3 minutes	5 minutes	5 minutes
Activity 9	5 minutes	--	10 minutes
Activity 10	5 minutes	10 minutes	10 minutes
Activity 11	3 minutes	5 minutes	5 minutes
Activity 12	40 minutes	60 minutes	60 minutes

Activity 13	10 minutes	10 minutes	10 minutes
TOTAL TIME	2 hours 46 minutes	2 hours 5 minutes	3 hours 45 minutes

Table 5.3 Time spent on each activity

5.3.1.3 Results obtained

After the execution of the activities designed for the experiment, different results were generated, those obtained from observation and statistical calculations. From the observation, it was identified that the groups that obtained poor results (in terms of the final product rating) were those that did not generate internal discussions to resolve doubts, did not fulfill the assigned role, and did not have the disposition to work as a group. It was also observed that following the entire process from the beginning was exhausting for the participants and that this generated a lack of commitment for the rest of the activity, due to its high cognitive load.

On the other hand, the experiment used a control group that did not use the process (UP) and a group that did (UM), to ensure that the differences in the final results were not only observed but statistically significant, the Student's T distribution was used (Neave, 2002), which allowed validation of the specific hypotheses shown in Table 5.1. Depending on the information to be analyzed, there are three types of t-tests a) t-test for means of two paired samples, this means data coming from the same people, i.e. comparison of the experimental group BEFORE and AFTER a stimulus (in this case the stimulus is the application of the process). The following two types of t-tests use data coming from two different groups, where one received the stimulus and the other did not (in this case, UP that did not use the process and UM that did): b) t-test for two samples with equal variances: c) t-test for two samples with unequal variances.

The calculations of the different Student's t-tests applied in this experiment were performed using the function offered by the Excel office automation package for the calculation of this test. The values used to perform this calculation were (See Table 5.4):

	T-tests type a)	**Type b) and c) t-tests**
Reliability level	95%	95%
Significance level	5%	5%
Observations or cases	9	9 (UM), 3 (UP)
Critical value in	Two tailed	Two tailed
Degrees of freedom	8	10

Table 5.4 Values used for T-tests

Initially, for t-tests of types b) and c) it was necessary to determine whether the variances of the values were equal or unequal, so Fisher's test is used (using the F-test function provided by the Excel office suite), where two hypotheses were defined:

- H_0 = variances are equal
- H_a = variances are different

In addition, in all three types of tests, the acceptance or rejection of the null hypothesis was considered:

- If the P-value or F-value <= significance level, the null hypothesis is rejected
- If the P-value or F-value > significance level, the null hypothesis is accepted

Considering the specific hypotheses, their respective variables and the values obtained, after applying the statistical analysis, the following results were generated and are shown in Table 5.5.

It is important to note that: different scales are used in Table 5.5 because they are different types of measures analyzed. Both individual and group descriptions of comprehension were rated by the activity coordinator from 0 to 5 (0 for those descriptions of comprehension that did not correspond to what they had to do in the activity, 5 for those descriptions that correctly wrote the activity) because they are rating scales used by the researchers, the other scales are based on previous studies that have used the analyzed questions with their respective scales as shown in the references in Table 5.2.

	Values type	T-test type	Results	Variable	Accepted hypothesis	Activity where the data are obtained
H.1.1	Grades between 0 and 5	a)	T-value (9) = 3,86; P (0.005)	1.1.a	H.1.1.2_a = There is a statistically significant difference in the average of grades between individual and group descriptions.	Activity 5 and Activity 10
	Grades between 0 and 5	b)	F-Value=0,27; T-value (9,3) = 2,61; P (0.026)	1.1.b	H.1.1.4_a = There is a statistically significant difference in the average of grades for group descriptions between UM and UP participants.	Activity 10
H.1.2	Very unclear (1) – Very clear (5)	--	81,6%	1.2.a	H.1.2.2_a = The perception percentage about the level of understanding that participants have before the descriptions of other group participants is greater or equal than 60%.	Activity 7
	Do not agree (1) - Completely agree (5)	--	73,9%	1.2.b	H.1.2.4_a = The perception percentage about the level of opinion that participants have before the descriptions of other group participants is greater or equal than 60%.	Activity 7
H.1.3	None (0) - Quite (4)	a)	T-value (9) = 4,95; P (0,011)	1.3.a	H.1.3.2_a = There is a statistically significant difference in the average of obtained results from the homogeneous understanding of the group before and after the use of the proposed process.	Activity 8 and Activity 11 for UM
	Nothing (0) – Quite (4)	a)	T-value (9) = 5,20; P (0,0008)	1.3.b	H.1.3.4_a = There is a statistically significant difference in the average of obtained results from differences in individual knowledge versus group knowledge, before and after the use of the proposed process.	Activity 8 and Activity 11 for UM
	None (0) - Quite (4)	b)	F-Value = 0,20; T-value (9,3) = 2,35; P (0,041)	1.3.c	H.1.3.6_a = There is a statistically significant difference in the average of obtained results from the homogeneous understanding between the UM and UP groups.	Activity 11

	Nothing (0) – Quite (4)	b)	F-Value = 0,82; T-value (9,3) = 3,90; P (0,002)	1.3.d	$H.1.3.8_a$ = There is a statistically significant difference in the average of obtained results from differences in individual knowledge versus group knowledge, between the UM and UP groups.	Activity 11
H.1.4	Strongly disagree (0) - Strongly agree (4)	b)	F-Value = 0,97; T-value (9,3) = 2,79; P (0,019)	1.4.a	$H.1.4.2_a$ = There is a statistically significant difference in the average of obtained results from the task of Construction between the UM and UP groups.	Activity 13
	Strongly disagree (0) - Strongly agree (4)	b)	F-Value = 0,70; T-value (9,3) = 2,32; P (0,043)	1.4.b	$H.1.4.4_a$ = There is a statistically significant difference in the average of obtained results from the task of Collaborative Construction between the UM and UP groups.	Activity 13
	Strongly disagree (0) - Strongly agree (4)	b)	F-Value = 0,61; T-value (9,3) = 2,30; P (0,044)	1.4.c	$H.1.4.6_a$ = There is a statistically significant difference in the average of obtained results from the task of Constructive Conflict between the UM and UP groups.	Activity 13
H.2.1	Grades between 0 and 5	b)	F-Value = 0,12; T-value (9,3) = 2,42; P (0,036)	2.1	$H.2.1.2_a$ = There is a statistically significant difference in the average of the grades from the results after applying the guide between the UP and UM groups.	Activity 12 (Questions section 1)
H.2.2	Total questions	b)	F-Value = 0,21; T-value (9,3) = 15,32; P (0,000000028)	2.2	$H.2.2.2_a$ = There is a statistically significant difference in the number of questions posed to the activity coordinator between the UM and UP groups.	During all activities
H.2.3	Strongly disagree (0) - Strongly agree (4)	b)	F-Value = 0,60; T-value (9,3) = 2,88; P (0,016)	2.3	$H.2.3.2_a$ = There is a statistically significant difference in the average of obtained results from perceived satisfaction by the participants about the attainment of the objectives between the UM and UP groups.	Activity 12 (Questions section 2)
H.2.4	Strongly disagree (0) - Strongly agree (4)	b)	F-Value = 0,09; T-value (9,3) = 1,36; P (0,204)	2.4.a	$H.2.4.1_0$ = There is no statistically significant difference in the average of obtained results from perceived satisfaction by the participants about process items between the UM and UP groups.	Activity 12 (Questions section 3)
	Strongly disagree (0) - Strongly agree (4)	b)	F-Value = 0,13; T-value (9,3) = 0,68; P (0,514)	2.4.b	$H.2.4.3_0$ = There is no statistically significant difference in the average of obtained results from perceived satisfaction by the participants about activity outcomes between the UM and UP groups.	Activity 12 (Questions section 4)

Table 5.5 Results for each specific hypothesis

Discussion of results

According to the observation, during the performance of the activity, it was identified that the participants of the UM groups, having the description of the process, had better execution of the activity, because they had a road map to reach the objective. On the contrary, in the UP groups, it was observed that their behavior in the execution of the activity was quite chaotic since they did not have clear guidelines to follow. In addition, it was possible to identify that in order to obtain better results, there should be an interest on the part of each participant in interacting with their group mates and giving the necessary contributions to achieve the objectives. However, it was also observed that the use of the complete process generates a high cognitive load since it is a process that contains many steps.

From the statistical results it was possible to determine that:

- $H.1.1.2_a$ can be accepted. In this way, it can be said that there is a significant difference between the grade's averages of the individual descriptions, compared to the group ones. According to what was previously said, it can be inferred that use of the process improved the understanding of participants.
- $H.1.1.4_a$ can be accepted. In this way, it can be said that there is a significant difference in the averages of the grades given to the group descriptions between the UM and UP groups. Concerning the prior information, it can be inferred that use of the process can generate a better group understanding.
- $H.1.2.2_a$ can be accepted. In this way, it can be said that in the UM groups, the average of the understanding of the individual descriptions of their colleagues is 81.6%. According to what was previously said, it can be inferred that there are no significant differences in understanding before interacting with the group because all participants may misunderstand the concepts and have the same mistakes.
- $H.1.2.4_a$ can be accepted. In this way, it can be said that in the UM groups, the average of the opinion of the individual descriptions of their colleagues is 73.9%. Concerning the prior information, it can be inferred that there are no significant discrepancies before performing a group discussion due to the fact that all participants may have the same doubts or the same mistakes.
- $H.1.3.2_a$ can be accepted. In this way, it can be said that for UM groups, there is a significant difference in the perception of the participants of their homogeneous understanding before and after the use of the process. With respect to the above, it can be inferred that the use of the process allows for a homogeneous understanding of what to do.
- $H.1.3.4_a$ can be accepted. In this way, it can be said that for UM groups there is a statistically significant difference in the average of obtained results from differences in individual knowledge versus group knowledge. With respect to the above, it can be inferred that with the use of the proposed process there are no discrepancies of each participant with regard to the group understanding, that is, at the end of the use of the process, all know what to do and agree with what has been defined by the group.
- $H.1.3.6_a$ can be accepted. With the UP group, the perception of homogeneous understanding was researched, only at the end, after creating a group description. In this way, it can be said that there is a statistically significant difference in the average of obtained results from the homogeneous understanding between the UM and UP groups.

With respect to the above, it can be inferred that using the process allows for a homogeneous understanding among the participants.

- $H.1.3.8_a$ can be accepted. With the UP group, the perception of discrepancy was researched, only at the end, after creating a group description. In this way, it can be said that there is a statistically significant difference in the average of obtained results from differences in individual knowledge versus group knowledge, between the UM and UP groups. With respect to the above, it can be inferred that using the process does not generate knowledge discrepancies with group members.
- $H.1.4.2_a$, $H1.4.4_a$, and $H1.4.6_a$ can be accepted. In this way, it can be said that there is a statistically significant difference between the perception results of the UM and UP groups, with respect to the tasks of a shared understanding (Construction, Collaborative Construction, and Constructive Conflict). With respect to the above, it can be inferred that the MU groups generated better results and these tasks were better fulfilled among the participants, due to the used process.
- $H.2.1.2_a$ can be accepted. At the end of the problem-solving activity, a final artifact was generated that was qualified by the coordinator, in this way, it can be said that there is a statistically significant difference in the grades between the UP and UM groups. With respect to the above, it can be inferred that the use of the process generates end products of the activity with better quality levels.
- $H.2.2.2_a$ can be accepted. In this way, it can be said that there is a statistically significant difference in the number of questions posed to the coordinator between the UM and UP groups, questions to solve doubts or concerns about the activity. With respect to the above, it can be inferred that this difference is due to the use of the process since it allowed to solve these questions internally.
- $H.2.3.2_a$ can be accepted. In this way, according to the results, it can be said that there is a statistically significant difference in the average of obtained results from perceived satisfaction by the participants about the attainment of the objectives between the UM and UP groups. With respect to the above, it can be inferred that the process allowed to obtain better satisfaction with the achievement of the proposed objectives by the activity.
- $H.2.4.1_0$ can be accepted. In this way, also according to the results, it can be said that there is no statistically significant difference in the average of obtained results from perceived satisfaction by the participants about process items between the UM and UP groups. With respect to the above, it can be inferred that for the participants it is a process that has many steps, that its application takes a long time and therefore generates a high cognitive load.
- $H.2.4.3_0$ can be accepted. In this way, also according to the results, it can be said that there is no statistically significant difference in the average of obtained results from perceived satisfaction by the participants about activity outcomes between the UM and

UP groups. With respect to the above, it can be inferred that that according to the perception of the participants, this is an extensive process, and therefore, the results of the activity may not be the best.

Conclusions of the experiment

According to the validation of hypotheses H.1.1, H.1.2, H.1.3, and H.1.4 related to the feasibility of the process, it can be said that the process is feasible to build shared understanding in a problem-solving activity. According to the validation of H.2.1, H.2.2, H.2.3, and H.2.4, it can be concluded that the process is partially useful in achieving the objectives of the problem-solving activity, but it cannot be assured that the process improves the participants' perception of satisfaction with its elements and with the outcomes of the activity. Considering that the process is perceived as feasible and partially useful, it can be inferred that although good results are obtained, there is a high cognitive load that needs to be improved.

Although existing measurement mechanisms were used for shared understanding combined with observation, the need for measurement instruments that are not based solely on perception is revealed, in addition to the need to include monitoring and assistance mechanisms that allow for maintenance during the development of the activity. In the same way, it is necessary to lighten the process to avoid cognitive load.

Threats to validity

Construct validity: the construction of shared understanding was observed and measured by participant perceptions, but the constructs underlying these behaviors are still unknown. To minimize subjectivity in the instruments supporting data collection, they were subjected to validations by expert personnel with expertise in process definition, and collaboration, where validations allowed for improvement and completion of process elements prior to the execution of the experiment.

Internal validity: the time invested for the execution of the study is extensive, and very long sessions are needed where participants in the final stages of the experiment may perceive fatigue that may influence the results. To try to mitigate this threat in the middle of the experiment, participants took a break without communicating with each other.

External validity: The activity that had to be performed with the participants was about scope definition in software process lines, this topic is hardly known by university students. This was mitigated by making socialization of the topic at the beginning of the activity to contextualize this topic, and also to choose students from subjects where this topic is taught.

The formats used and the evidence of what was done in this experiment can be seen in *Annex 7*.

5.3.2 Validation 1 - Exploratory study

An exploratory study is usually conducted when the objective is to examine a topic or research problem that has not been studied or addressed before. This type of study serves to increase the degree of knowledge of relatively unknown phenomena and to obtain information on the possibility of carrying out a more complete investigation on a particular context (Hernandez Sampieri, Paulina Mendoza, & Méndez Valencia, 2018). That is why it was decided to conduct a study of this type, to have more familiarity with the context, and to find flaws and possible needs in the process defined in its first version.

5.3.2.1 Exploratory study design

Context and objective of the exploratory study

The exploratory study was carried out in a university environment, where 75 students from the Universidad del Cauca - UC (Colombia) participated, all of them systems engineering students, 37 students from the software engineering I course belonging to the fifth semester (7 women and 30 men) and 38 students from the software engineering II course belonging to the sixth semester (10 women and 28 men), who used the process. And 75 students from the Corporación Universitaria Comfacauca, Unicomfacauca - UF (Colombia) participated, all of them systems engineering students, 27 students from the software engineering I course belonging to the fifth semester (10 women and 17 men), and 48 students from the software engineering II course belonging to the sixth semester (15 women and 33 men), who did not use the process. Heterogeneous groups of 5 participants were formed with these students, resulting in 15 groups in each university. For this study, the characteristic of learning styles was also selected for the formation of the groups, and likewise, the software tool called Collab [53] was used to support this grouping. On the other hand, the same problem-solving activity used in the experiment was used, in order to make as few variations as possible, analyze the results obtained with the application of the process, and observe what happens in the context.

The purpose of the exploratory study was to inquire about the construction of shared understanding through the use of the process, in its first version, in a problem-solving activity. The research question of the study was determined as follows: *Does the process encourage and improve the shared understanding in a problem-solving activity?*

Experiment hypothesis

Considering the objective of the experiment, the following hypotheses were evaluated:

- The process encourages the construction of shared understanding in a problem-solving activity
- The process improves the construction of shared understanding in a problem-solving activity

In order to validate these hypotheses, the following variables were considered:

- Improvement in the group descriptions: this is the level of improvement found in the descriptions after the execution of the process. This variable represents the statistically significant difference between the notes that were given to the individual and group descriptions.
- Improvement in the UC and UF descriptions: this is the level of improvement found in group descriptions after the execution of the process. This variable represents the statistically significant difference in the notes given to the group descriptions between UC and UF groups.
- Understanding other descriptions: this comprises the level of understanding that a participant has given the descriptions of what they should do from the activity, from other group participants. This variable represents a perceptual judgment of understanding of other descriptions.
- The opinion of other descriptions: this is the level of opinion that a participant has with the descriptions of other group participants, of what they should do with the activity. This variable represents a perceptual judgment of opinion of other descriptions.
- Improvement in homogeneous understanding: this is the level of improvement in the homogeneous understanding of the group of the activity to be undertaken, after use of the proposed process. This variable represents the statistically significant difference between the perceptual judgment of homogeneous understanding before and after the use of the proposed process.
- Improvement in the discrepancy: the level of improvement in the discrepancy by each participant compared to other participants about the activity, after the use of the proposed process. This variable represents the statistically significant difference between the perceptual judgment of discrepancy before and after the use of the proposed process.
- Improvement in homogeneous understanding in UC and UF: this is the level of improvement in the homogeneous understanding of the group of the activity to be developed, after the use of the process. This variable represents the statistically

significant difference of the perceptual judgment of homogeneous understanding between the UC and UF groups.

- Improvement in the discrepancy in UC and UF: this is the level of improvement in the discrepancy by each participant compared to other participants about the activity, after the use of the process. This variable represents the statistically significant difference of the perceptual judgment of discrepancy between the UC and UF groups.
- Improvement in the Construction activity: this is the level of improvement in the Construction activity results, following use of the process. This variable represents the statistically significant difference of the perceptual judgment of Construction activity results between the UC and UF groups.
- Improvement in the Co-construction activity: this is the level of improvement in the Co-construction activity results, after the use of the process. This variable represents the statistically significant difference of the perceptual judgment of Co-construction activity results between the UC and UF groups.
- Improvement in the Constructive conflict activity: the level of improvement in the Constructive conflict activity results, after the use of the process. This variable represents the statistically significant difference of the perceptual judgment of Constructive conflict activity results between the UC and UF groups.
- Improvement in the quality of the results: this is the level of improvement in the quality of the final results obtained in performing the problem-solving activity, after the use of the process. This variable represents the statistically significant given difference of scores to the final results between the UC and UF groups.
- Improvement in perception about the achievement of the objectives: this is the level of improvement in the perception of the participants, about the achievement of the objectives, after the use of the process. This variable represents the statistically significant difference in the perceptual judgment of objective achievement between the UC and UF groups.
- Improvement in perception about the satisfaction with the process elements: this is the level of improvement in the perception of the participants, about the satisfaction with the process elements, after making use of the process. This variable represents the statistically significant difference in the perceptual judgment of satisfaction with the process elements between the UC and UF groups.
- Improvement in perception about the satisfaction with the activity outcome: this comprises the level of improvement in the perception of the participants, about the activity outcome, after the use of the process. This variable represents the statistically significant difference in the perceptual judgment of satisfaction with the outcome of the activity between the UC and UF groups.

To validate the hypothesis on "Process *encourages* the construction of shared understanding in a problem-solving activity", variables 3, 4, 9, 10, 11, 12, 13, 14 and 15 were specifically considered.

To validate the hypothesis about "Process *improves* the construction of shared understanding in a problem-solving activity", the variables 1, 2, 5, 6, 7 and 8 were specifically considered.

Design of experiment activities

The activities, estimated time and support instruments used were the same as the experimental design shown previously in section 5.3.1.1.

5.3.2.2 Exploratory study execution

The UC groups applied all the phases, activities, and tasks specified in the process, using the tools provided for their support, spending a time of 3 hours and 40 minutes. The UF groups, on the other hand, carried out the same designed collaborative activity, where the teacher designed the necessary elements for the activity without a specific guide, and simply among the groups, they reached the solution of said activity without following the proposed process, spending 2 hours and 50 minutes, from the design of the activity to the analysis of the results and the respective survey.

5.3.2.3 Results obtained

After the execution of the activities designed for the exploratory study, different results were generated, those obtained from observation and statistical calculations. From the observation, it was identified that each of the people who applied the process needed more detailed steps to know what to do in each task, and they needed more detailed support to execute them. It was also observed that designing complete activities is an arduous task that requires experience and knowledge to be able to consider all the factors that affect it. On the other hand, the study used a control group that did not use the process (UF) and a group that did (UC), as in the previous experiment, to ensure that the differences in the final results were not only observed but statistically significant, Student's t-distribution was used to validate the hypotheses, considering the 3 types of existing tests.

The calculations of the different types of Student's t-tests applied in this study were performed using the function offered by the Excel office automation package for the calculation of this test. The values used to perform this calculation were (See Table 5.6):

	T-tests type a)	Type b) and c) t-tests
Reliability level	95%	95%
Significance level	5%	5%
Observations or cases	15	15 (UC), 15 (UF)
Critical value in	Two tailed	Two tailed
Degrees of freedom	14	28

Table 5.6 Values used for T-tests

For this study, the hypotheses for Fisher's test were considered as in the previous experiment.

- H_0 = variances are equal
- H_a = variances are different

And in the three types of tests, the acceptance or rejection of the null hypothesis was considered.

- If the P-value or F-value <= significance level, the null hypothesis is rejected
- If the P-value or F-value > significance level, the null hypothesis is accepted

Considering the hypotheses, after applying the statistical analysis, the following results were generated and are shown in Table 5.7.

Variable	Values type	T-test type	Results	Accepted hypothesis
1	Scores between 0 and 5	a)	T-value = -5,130; P (0,00015)	Alternative = There is a statistically significant difference in the mean of scores between the individual and group descriptions.
2	Scores between 0 and 5	b)	F-Value=0.261; T-value = 2,98; P (0,0059)	Alternative = There is a statistically significant difference in the mean of scores for group descriptions between UC and UF participants.
3	Very unclear (1) – Very clear (5)	--	82%	Alternative = The percentage of perception about the level of understanding that participants have regarding the descriptions of the other participants in the group is greater than or equal to 60%.
4	Do not agree (1) - Completely agree (5)	--	75%	Alternative = The percentage of perception about the level of opinion that the participants have regarding the descriptions of other participants in the group is greater than or equal to 60%.
5	None (0) - Quite (4)	a)	T-value = -5,233; P (0,00013)	Alternative = There is a statistically significant difference in the mean of the obtained results from the homogeneous understanding of the group before and after the use of the proposed process.
6	Nothing (0) – Quite (4)	a)	T-value = 2,434; P (0,029)	Alternative = There is a statistically significant difference in the mean of the obtained results from differences in individual knowledge versus group knowledge, before and after the use of the proposed process.
7	None (0) - Quite (4)	b)	F-Value = 0.604; T-value = 5,687; P(0,000004)	Alternative = There is a statistically significant difference in the mean of the obtained results from the homogeneous understanding between the UC and UF groups.
8	Nothing (0) – Quite (4)	b)	F-Value = 0.933; T-value = -5,134; P (0,000019)	Alternative = There is a statistically significant difference in the mean of the obtained results from differences in the individual knowledge versus the group knowledge, between the UC and UF groups.
9	Strongly disagree (0) - Strongly agree (4)	b)	F-Value = 0.235; T-value = 4,932; P (0,000033)	Alternative = There is a statistically significant difference in the mean of the results obtained from the activities of Construction between the UC and UF groups.

10	Strongly disagree (0) - Strongly agree (4)	b)	F-Value = 0.512; T-value = 5,124; P (0,000020)	Alternative = There is a statistically significant difference in the mean of the results obtained from the activities of Co-Construction between the UC and UF groups.
11	Strongly disagree (0) - Strongly agree (4)	b)	F-Value = 0.826; T-value = 4,379; P (0,00015)	Alternative = There is a statistically significant difference in the mean of the results obtained from the activities of Constructive conflict between the UC and UF groups.
12	Scores between 0 and 5	b)	F-Value = 0.702; T-value = 6.150; P (0.000001)	Alternative = There is a statistically significant difference in the mean of the scores from the results after applying the guide between the UF and UC groups.
13	Strongly disagree (0) - Strongly agree (4)	b)	F-Value = 0.407; T-value = 4,276; P (0,0002)	Alternative = There is a statistically significant difference in the mean of the results obtained from perception of participants about the achievement of objectives between the UC and UF groups.
14	Strongly disagree (0) - Strongly agree (4)	b)	F-Value = 0.596; T-value = 0,065; P (0,948)	Null = There is not any statistically significant difference in the mean of the results obtained from satisfaction perceived by the participants about process items between the UC and UF groups.
15	Strongly disagree (0) - Strongly agree (4)	b)	F-Value = 0.996; T-value = -0,493; P 0,625)	Null = There is not any statistically significant difference in the mean of the results obtained from satisfaction perceived by the participants about activity out-comes between the UC and UF groups.

Table 5.7 Results for each specific hypothesis

Discussion of results

Upon executing this exploratory study and applying the Student's t-test to the resulting values generated from the different surveys and analysis of what was done, it was obtained that in variables 3, 4, 9, 9, 10, 10, 11, 12, and 13, the alternative hypotheses were accepted, with which it can be established that the use of the process generates greater understanding and a favorable opinion about the understandings of the other group members in the collaborative activity, a greater individual construction of understanding, debates, and discussions of ideas, which after the conflict generates a group understanding (categories defined in (Bittner & Leimeister, 2014)), better results and a perception in the participants of satisfaction with the achievement of the objectives of the collaborative activity. With these hypotheses accepted, it can be that the process fosters the construction of a shared understanding in a problem-solving activity in an acceptable way. However, in the measurement of variables 14 and 15 the null hypotheses were accepted, with which it can be established that the process does not generate satisfaction in the participants about the elements (phases, activities, tasks, work products, roles) that make up the process and about the results that the participants obtain at the end of the collaborative activity.

On the other hand, according to the results obtained in the measurement of variables 1, 2, 5, 6, 7, and 8, in which their alternative hypotheses were accepted, it can be established that the use of the process generates better individual and group understanding, which is reflected in the deliverables made, a homogeneous understanding among the members of the groups, and a better group knowledge. Accepting these hypotheses, it can be concluded that the process improves shared understanding in the groups that carry out a collaborative activity. The evidence of what was done in this exploratory study can be seen in *Annex 8*.

5.3.3 Validation 2

5.3.3.1 New elements of version 2 of the process

Based on the results obtained in the validation of version 1 (experiment and exploratory study), some changes, corrections, and improvements were made, thus obtaining version 2 of the process. These new elements were:

- The Post-Process phase is detailed.
- For each phase, workflows are specified, a set of activities, a set of tasks are defined for each activity, and a set of steps, roles, work products (inputs, outputs) are defined for each task.
- Documents are added to support the monitoring of each step to verify that they are executed as required and designed.
- Assistance mechanisms are added to execute those tasks that are more vital and need support to be carried out.
- As an assistance mechanism, a set of 6 fully designed activities are provided to ensure shared understanding building and problem-solving, which can be selected and/or adapted by the person in charge of the collaborative activity design.
- Shared understanding measurement mechanisms are provided from several dimensions, individual, group, individual results, group results, self-assessment, and a measurement mechanism using concept maps.
- Mechanisms are provided to measure participants' performance from different dimensions, individual, group, and self-evaluation, and considering different aspects.
- A measurement mechanism is provided to validate compliance with the solution of the problem.

5.3.3.2 Expert validation design

The objective of the expert validation was to analyze the structure of the second version of the process, validating the syntax and semantics of the process, in such a way that some errors, excess or missing elements in the process specification made in SPEM 2.0 (OMG, 2007) were identified.

<u>Context of the experts</u>

Three experts in software and process engineering participated in the validation. The experts were: Pablo Ruiz who has a PhD in Electronics Sciences from the Universidad del Cauca, with 10 years of experience in software engineering, design, construction, specification and improvement of processes and process lines. Valentina Vergara and

Anderson López, systems engineers from Unicomfacauca, who have 2 years of experience in process design and specification, deepening in SPEM 2.0 modeling.

Design of validation activities

To carry out the validation by expert judgment, a set of activities were designed that made it possible to perform all the actions necessary to obtain the expected results. These activities, with their expected duration and the instruments used, are presented in Table 5.8 below.

Experiment activity	Planned duration	Support instruments
Activity 1: The problem to which the process intends to provide a solution is socialized	10 minutes	Problem presentation, problem tree and literature review
Activity 2: The objective of the expert evaluation is shared with the participant	5 minutes	Presentation of the objective
Activity 3: Version 2 of the process is socialized in general	10 minutes	Presentation with a general explanation of the process, without going into details
Activity 4: The experts are given the process specification in SPEM 2.0 for their detailed analysis	1 hour	Web publication of the process in SPEM 2.0
Activity 5: Break	10 minutes	
Activity 6: A survey is given to the experts so that they can give their point of view and observations	30 minutes	Survey document
Activity 7: The experts are thanked, and the session is closed	5 minutes	
Total time spent	2 hours	

Table 5.8 Design of expert validation activities

5.3.3.3 Expert validation execution

All the activities planned for the expert validation were executed, using the tools provided for their support, using a time of 2 hours and 20 minutes. Several important elements were obtained to improve the specification of the process and give it a better structure, which will be shown in the following section.

5.3.3.4 Results obtained

Survey results

- For each of the phases of the process, it was inquired whether the names and descriptions were adequate, clear and whether the objective of each phase was understood. The results showed that 66.7% of the participants said yes, and 33.3% said that they needed to be improved.
- For each of the activities of the Pre-Process phase, it was asked whether the names, descriptions, and workflows were adequate and clear, and it was determined that 33.3% of the experts thought they were adequate and clear and 66.7% thought they should be improved. The same was done for the activities of the Process phase, where it was

determined that 66.7% of the experts thought they were adequate and clear and 33.3% thought they should be improved. The same was done for the activities of the Post-Process phase, where 66.7% of the experts thought they were adequate and clear and 33.3% thought they should be improved.

- For each of the specific tasks of each activity, and for each phase, a more detailed analysis was made, where the experts were asked if the objective of each task was understood and if the names and descriptions were adequate and clear. If the task had associated input and output work products and if these had an adequate, clear, and understandable description, and if they had associated adequate guidance. Whether the task had primary performer roles, and additional performer roles appropriate to what they were to perform, with clear, understandable role descriptions and associated skills. If the task defined clear and adequate steps that allowed the complete and correct execution of the task. For this inquiry, observations and recommendations for improvement were solicited if necessary for each specific element.

The survey conducted can be found in *Annex 9*.

Elements to correct or improve the process

Based on the survey conducted, where the experts made their observations and corrections to the structure of the process regarding its syntax and semantics, it was possible to identify the need to modify several elements, among which were the following:

- The descriptions of all Pre-Process activities are not clear, and it is necessary to specify the need to execute them based on theory.
- There are workflows that are not clear to follow in the activities.
- Activities should not have assigned roles; roles are task specific.
- Monitoring should be specified for each activity, where monitoring is done for each step of the tasks and not specified as work products in each task.
- Some task names are not clear.
- There are work products that do not correspond as task inputs and outputs.
- It is necessary to review the roles assigned to the tasks so that support between roles can be generated.
- There are attendance documents that are not clear to follow.
- It is necessary to establish a color code for the attendance documents to know what is mandatory to fill out and what is not, and if it is information that is brought from other tasks.
- It is necessary to define if all the tasks are always mandatory.

5.3.4 Validation 3

The following experiment was intended to validate the completeness, usefulness, and ease of use of version 3 of the process, which was called THUNDERS (CollaboraTive work through sHared UNDErstanding in pRoblems-solving activitieS), each of the new elements of this version are specified below. In this experiment, THUNDERS was applied in the requirements activities for the development of a software tool for information management and data processing for a livestock association. The following sections show in detail what was done to analyze the results of this experiment (In *Annex 10*, a review of the literature on the construction of shared understanding in requirements engineering is made, as an important need in this context, so that a common language can be achieved on what is desired to build as a software product and that all participants, in the different activities necessary to obtain the final requirements, can have adequate coordination and communication on the context and user needs to be met in the development process).

5.3.4.1 New elements of version 3 of the process

Based on the results obtained in the validation of version 2 (by experts), some changes, corrections, and improvements were made, thus obtaining version 3 of the process. These new elements were:

- Syntax and semantic errors of the process are corrected, referring to what is specified by SPEM 2.0, which do not correspond.
- The assignment of both input and output work products is corrected, in order to avoid isolated or overloaded products.
- More representative names are given to tasks and work products (inputs and outputs), in order to make them clearer.
- All descriptions of phases, activities, and tasks are improved, including theoretical support to define each description.
- The workflows of the activities and of each task are improved.
- Roles in each task are revised and re-distributed, looking for support among them.
- Tasks are defined in each activity, exclusively dedicated to monitoring each step, focused on verifying compliance with the specified so that corrections or improvements can be made at the required time.
- Assistance documents are reviewed to redefine the wording of the steps to be followed, and a color code is included to help with their completion.
- For each task of the process, it is determined which ones must be mandatory to execute and which ones are not, when it is required to define a collaborative activity since it is designed, it is executed, and the different elements are validated.

5.3.4.2 Experiment design

Context and objective of the experiment

THUNDERS was applied in a real environment, where it was necessary to obtain the requirements for the development of a software tool for ASPROLGAN (Asociación de Productores Lácteos y Agro ganaderos del Municipio de Popayán), which is located in the city of Popayán, department of Cauca - Colombia. It is a nonprofit association made up of 94 associates who in turn influence 470 people who belong to their families. The association as an organization must support its administrative management processes such as: planning, organization, direction, and control, but these processes are executed manually and not in the best way, due to the fact that there is not enough standardized, available, and accessible information. Therefore, the need of the association was mainly to improve information management and data processing by using a software tool for the dairy sectors that belong to the association. For the implementation of THUNDERS, 10 members of the development team and 4 members of the association participated. Two heterogeneous groups were formed as follows: Group 1 (G1) project manager, 2 developers, 1 analyst, 1 architect, and 2 members of the association. Group 2 (G2) the project coordinator, 2 developers, 1 analyst, 1 architect, and 2 members of the association. For the context of this work, the problem to be solved consisted of obtaining the set of requirements that the software tool that was in charge of the processes of information management and data processing in the dairy sectors of the indigenous and peasant community of the San Juan and San Ignacio villages belonging to ASPROLGAN should have.

The objective of the experiment was to inquire about the completeness, usefulness, and ease of use of THUNDERS for the construction of shared understanding in the execution of requirements engineering activities. In this sense, the research question was defined as *How complete, useful, and easy to use is THUNDERS for the construction of shared understanding*? This experiment had a unit of analysis, which was the real context, where requirements engineering activities were performed for the construction of a software tool for ASPROLGAN, using the proposed process.

Experiment hypothesis

Considering the research question, the following hypotheses were intended to be evaluated:

- THUNDERS is complete in terms of having the necessary elements for the construction of shared understanding and execution of requirements engineering activities.

- THUNDERS is useful for the construction of shared understanding and execution of requirements engineering activities.
- THUNDERS is easy to use for building shared understanding and executing requirements engineering activities.

In order to refine the above hypotheses, the following specific hypotheses with their respective variables were raised (see Table 5.9):

	Hypothesis	Variables
Completeness	H.1.1 Users applying THUNDERS perceive that its elements are sufficient for building shared understanding	*Completeness of THUNDERS elements to build a shared understanding*: It represents the degree of completeness perceived by each person in applying THUNDERS. It is a perceptual judgment of the completeness of the approach in building a shared understanding
	H.1.2 Users applying THUNDERS perceive that its elements are sufficient for the execution of requirements engineering activities	*Completeness of THUNDERS elements for the execution of requirements engineering activities*: Represents the degree of completeness perceived by each person when applying THUNDERS. Is a perceptual judgment of the completeness of the proposal when executing requirements engineering activities
Utility	H.2.1 Users applying THUNDERS perceive the process to be useful for the construction of shared understanding	*Usefulness of THUNDERS for the construction of shared understanding*: Represents the degree of usefulness perceived by each person when applying THUNDERS. It is a perceptual judgment of the usefulness of the proposal when building a shared understanding
	H.2.2 Users applying THUNDERS perceive the process to be useful for the execution of requirements engineering activities	*Usefulness of THUNDERS for the execution of requirements engineering activities*: Represents the degree of usefulness perceived by each person when applying THUNDERS. Is a perceptual judgment of the usefulness of the proposal in executing requirements engineering activities
Ease of use	H.3.1 Users who apply THUNDERS perceive the process to be easy to use for the construction of shared understanding	*Ease of use of THUNDERS for building shared understanding*: Represents the perceived degree of ease of use with which a person can apply THUNDERS. It is a perceptual judgment of the effort required to apply it when building a shared understanding
	H.3.2 Users who apply THUNDERS perceive the process to be easy to use for the execution of requirements engineering activities	*Ease of use of THUNDERS for the execution of the requirements engineering activities*: Represents the perceived degree of ease of use with which a person can apply THUNDERS. It is a perceptual judgment of the effort required to apply it to execute requirements engineering activities

Table 5.9 Experiment specific hypothesis

<u>Design of experiment activities</u>

In order to execute the experiment, a set of activities were designed, which allowed carrying out all the necessary actions to obtain the expected results. These activities, with their expected duration and the instruments used, are presented in the following Table 5.10.

Experiment activity	Planned duration	Support instruments
Activity 1: Execution of the Pre-Process phase	1 hour and 30 minutes	THUNDERS web publication is provided to guide each of the activities, tasks, and steps, which contains each of the assistance documents to execute these phases.
Activity 2: Execution of the Process phase	4 hours	
Break	10 minutes	None.
Activity 3: Execution of the Post-Process phase	45 minutes	THUNDERS web publication is provided to guide each of the activities, tasks, and steps, which contains each of the assistance documents to execute this phase.

Activity 4: Survey	10 minutes	Survey format where each participant must answer, according to his/her criteria and experience, if THUNDERS is complete, useful, and easy to use in building shared understanding and executing the requirements engineering activities.
		TOTAL TIME: 6 hours 35 minutes

Table 5.10 Design of experiment activities

5.3.4.3 Experiment execution

For this experiment, there was participation of 14 people who assumed different roles during the application of THUNDERS. These participants executed the activities defined in the process, and the person in charge of the corresponding task, selected those tasks, which in his consideration, were necessary for this context, executing the steps specified for those selected tasks. In this way, use was made of the tools and assistance documents provided for their support. Specifically, for the Process phase, where the collaborative activity was to be executed, two groups were formed, seeking to have at least one representative from each area in each of the groups formed, in order to guarantee heterogeneity based on the knowledge and experience of this context. The idea of these two groups was to divide the scenarios of the association so that each one would be in charge of a set of requirements and thus be able to use the process to carry out what was requested. The following defines the activities of the experiment with the time spent and the specific THUNDERS tasks that were applied (See Table 5.11).

Activity	THUNDERS tasks performed	G1 y G2	Estimated time
Activity 1	To identify the activity topic, To monitor the tasks to define the topic of problem-solving activity, To identify the activity problem, To describe the activity (The activity proposed by the process, "Brainstorming", was selected), To define the activity objectives, To define the activity success criteria, To detail the collaborative activity, To monitor the tasks to design the problem-solving activity, To organize the groups for the activity, To monitor the tasks to define the groups, To design verification of compliance with the problem (The assistance mechanism was selected), To design verification of the shared understanding construction (The mechanisms of individual and group products, individual and group construction and self-appraisal were selected), To design verification of participants performance (The assistance mechanisms were selected), To monitor the tasks to design the verification methods.	2 hours	1 hour and 30 minutes
Activity 2	**First session**: To organize groups and assign roles, To monitor the task to form the groups, To socialize the problem to be solved, To socialize collaborative activity, To monitor the task to describe the problem-solving activity, To understand individually and in groups, To verify the initial shared understanding, To select the problem solution to be implemented. **Second session**: To implement the problem solution, To verify the problem solution, To verify the final shared understanding, To monitor the task to develop collaborative activity.	Two sessions were held on different days, each lasting 2 hours. Total 4 hours.	4 hours
Break	--	5 minutes	10 minutes
Activity 3	To verify compliance with the problem, To monitor the tasks to verify compliance with the problem, To verify the individual and group performance, To monitor the tasks to verify the individual and group performance, To end the activity, To monitor the tasks to close the activity.	1 hour	45 minutes
Activity 4	--	15 minutes	10 minutes
	TOTAL TIME	7 hours 20 minutes	6 hours 35 minutes

Table 5.11 Time spent on each activity and THUNDERS tasks performed

According to the previously defined activities of the experiment, specifically in the Process phase, the execution of the activities of the requirements engineering was carried out, the following (in Figure 5.3) shows the correspondence of how the specific tasks of the chosen collaborative activity called "Brainstorming" were carried out, with respect to the requirements engineering (Sommerville, 2011), which served as a basis to finally obtain a set of requirements that meet the needs of the end-users of the system and a shared understanding between the representatives of the association and the development team.

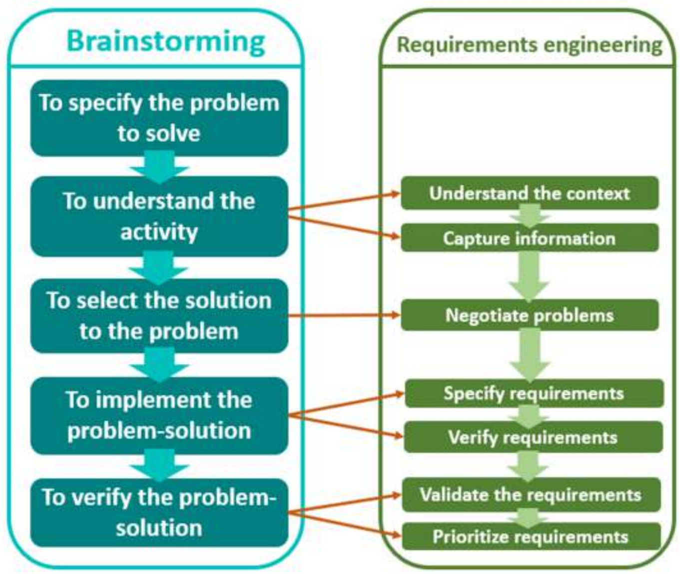


Figure 5.3 Correspondence between Brainstorming and requirements engineering activities

5.3.4.4 Results obtained

The qualitative analysis was performed based on the survey completed by members of the development team and members of the association who participated in the THUNDERS application. The survey responses were based on the Linkert scale, with 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 on option, and 5 for the totally agree option. Based on the initially formulated hypotheses, the following null hypotheses were posed.

- H.1.1$_0$, π_1 <= 60%, where π_1 is the percentage of perception that evaluates that THUNDERS activities, tasks, and steps are sufficient for the construction of shared understanding

- H.1.2$_0$, π_2 <= 60%, where π_2 is the percentage of perception that evaluates that THUNDERS activities, tasks, and steps are sufficient for the execution of requirements engineering activities
- H.2.1$_0$, π_3 <= 60%, where π_3 is the percentage of perception that evaluates that THUNDERS is useful for the construction of the shared understanding
- H.2.2$_0$, π_4 <= 60%, where π_4 is the percentage of perception that evaluates THUNDERS to be useful for the execution of requirements engineering activities
- H.3.1$_0$, π_5 <= 60%, where π_5 is the percentage of perception that evaluates that THUNDERS is easy to use for shared understanding building
- H.3.1$_0$, π_6 <= 60%, where π_6 is the percentage of perception that evaluates that THUNDERS is easy to use for the execution of requirements engineering activities

From the null hypotheses, the following alternative hypotheses were obtained:

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

From the results obtained in the survey, it was found that:

- According to the analysis of THUNDERS activities, tasks, and steps to determine whether they are sufficient for the construction of shared understanding, the percentage of participants' perception is 68.53%, which determined that H.1.1 can be accepted, and it can be said that THUNDERS is complete for the construction of shared understanding. Similarly, the percentage of participants' perception is 72.3%, which determined that H.1.2 can be accepted, and it can be said that THUNDERS is complete for the execution of requirements engineering activities
- For the analysis of THUNDERS usefulness, the percentage of participants' perception is 75.4%, which determined that H.2.1 can be accepted, and it can be said that

THUNDERS is useful for building shared understanding. Similarly, the percentage of participants' perception is 67.6%, which determined that H.2.2 can be accepted, and it can be said that THUNDERS is useful for the execution of requirements engineering activities.

- For the analysis of the ease of use of THUNDERS, the percentage of participants' perception is 55.2%, which determined that H.3 .1 can be rejected, and it can be said that THUNDERS is not easy to use for the construction of shared understanding Similarly, the percentage of participants' perception is 46.5%, which determined that H.3.2 can be rejected, and it can be said that THUNDERS is not easy to use for the execution of requirements engineering activities.

Discussion of results

According to the validation performed in this context, with the specific hypotheses H.1.1, H.1.2, H.2.1, and H.2.2, which were accepted considering the perception of the participants, therefore, it can be inferred that the main hypotheses are accepted, determining that: THUNDERS using the collaborative activity called Brainstorming, is complete and useful, i.e. it has the necessary elements, contains elements that are organized and coherent in their definition for the construction of shared understanding and execution of requirements engineering activities. However, in the validation of the specific hypotheses H.3.1 and H.3.2, which were rejected, it was determined that THUNDERS is not easy to use for the construction of shared understanding and the execution of requirements engineering activities, since it contains many tasks that must be followed. To see the evidence and the survey applied to the participants see the *Annex 10.*

5.3.5 Validation 4

The following validation was intended to obtain the support of experts in collaboration issues, to select the tasks that were or were not mandatory in the execution of the process in its version 4, in order to make it lighter and easier, and thus, to adapt it to specific contexts, being as extensive or light as required. Each of the new elements of the version submitted for validation is specified below.

5.3.5.1 New elements of version 4 of the process

Based on the results obtained in the validation of version 3 (in the experiment in the context of requirements engineering), some changes, corrections, and improvements were made, thus obtaining version 4 of the process. These new elements were:

- Improved work products (input and output) that were not well assigned

- Improved workflows to make them clearer to execute
- Attendance documents were updated in order to obtain better support

5.3.5.2 Expert validation design

The objective of the validation by the experts was to determine, according to their perception, knowledge, and experience, which of the tasks that make up the fourth version of the process, they consider being mandatory or optional to perform when a collaborative activity is to be carried out, from its design to its completion. In addition to determining when a task is considered optional, the cases, moments, or types of collaborative activities that require these tasks to be executed. They were also asked to comment about the name of the activity, its description, or the elements that they consider should be improved, included, or eliminated.

<u>Context of the experts</u>

Five experts in collaboration topics participated in the validation. The experts were: Andrés Solano, Manuel Ortega, Rosanna Costaguta, who have more than 5 years of experience; Oscar Revelo and Marta Cecilia Camacho with experience between 1 and 5 years in collaboration in different context.

<u>Design of validation activities</u>

To carry out the validation by expert judgment, a set of activities was designed that made it possible to carry out all the actions necessary to obtain the expected results. These activities, with their expected duration and the instruments used, are presented in Table 5.12.

Experiment activity	Planned duration	Support instruments
Activity 1: The problem to which the process intends to provide a solution is socialized	3 minutes	Google form to fill out the survey and share the information.
Activity 2: The objective of the expert validation is shared with the participant	2 minutes	
Activity 3: Show each of the tasks with their respective descriptions of the process version 4	1 hour	
Activity 4: A survey is given, so that they can give their points of view and observations	1 hour	
Total time spent	2 hours and 5 minutes	

Table 5.12 Design of expert validation activities

5.3.5.3 Expert validation execution

All the activities foreseen for the expert validation were executed, using the tool foreseen for its support, using a time of 2 hours and 30 minutes. Several important elements were obtained to improve the variability of the process, obtaining which tasks should be mandatory in any context and which are optional depending on certain specific elements. In addition to obtaining elements to improve the process.

5.3.5.4 Results obtained

From the survey format, where the experts made their observations and corrections, the new variability assignment for each of the tasks was obtained, which is part of the latest version of the process shown in this monograph. In addition, it was possible to identify the need to modify some elements of the process, among which the following are found:

- It is necessary to change the name of the phases and some tasks since they generate some confusion, and their objective is not very clear from the moment the name is read.
- The order of some tasks is not appropriate.
- Recommendations were given to consider in the steps of each task and in the assistance documents.

The survey conducted and the answers given can be seen in *Annex 11.*

5.3.5.5 Validation with AVISPA

The fourth version of the process was also subjected to a quality validation of its SPEM 2.0 specification using AVISPA-Method (Incremental Method for Visual Analysis of Process Models) (Camacho, Hurtado-Alegria, & Ruiz-Melenje, 2016), where some errors in its definition and formalization were identified. This validation method allows the evaluation of process models at a lower cost than their evaluation in the real application, using an analysis and visualization tool for software process evaluation called AVISPA (Hurtado, Bastarrica, & Bergel, 2013). The method defines the following activities to guide the validation: a) Design the process model: a version of the process model (SPEM version) is designed and formalized. b) Export the process model: the SPEM version of the process model is exported to an XML version. c) Examine the process with AVISPA-Method: the process model (XML version) is loaded into the AVISPA tool. Then, in each of the views generated in AVISPA and with the help of the error patterns (Camacho, Hurtado-Alegria, & Ruiz-Melenje, 2016), potential problems and opportunities for improvement of the model are identified and located. d) Perform an analysis and results report: the problems identified in the process model are reviewed and discussed. This analysis requires the review of the process model in its original format (SPEM version). At the end of the review, the real problems in the process model are identified, as well as possible improvements to be made. e) Make adjustments: corrections are made to the process model based on the errors and suggestions for improvement identified. The following section shows an analysis of the results obtained from the application of the AVISPA Method in the evaluation of the process model. The results are detailed from the three graphical views (tasks, roles, and work products) provided by AVISPA, each of which addresses a specific aspect of the process model (Hurtado, Bastarrica , & Bergel, 2013).

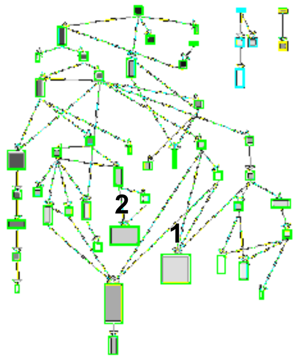


Figure 5.4 Task view

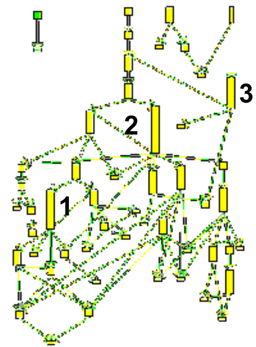


Figure 5.5 View about over-demanded work products

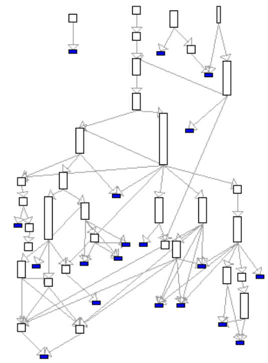


Figure 5.6 View about unnecessary work products

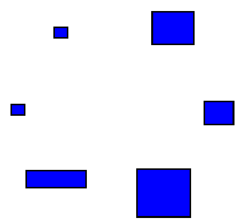


Figure 5.7 Role view

<u>Task view of the process model</u>

The task view provided by AVISPA shows the process from the perspective of the tasks performed during the execution of the process model. In this view, each rectangular node represents a specific task of the process and the attributes of each node provide information about the process under analysis (Hurtado, Bastarrica , & Bergel, 2013). Figure 5.4, presents the results obtained when evaluating THUNDERS with respect to the tasks, and according to the pattern of errors, independent subprojects (Camacho, Hurtado-Alegria, & Ruiz-Melenje, 2016) can be identified, that is, there are two disconnected or isolated sets of tasks (subgraphs at the top of the figure), which refers to the fact that these sets of tasks do not add value to the process objective and, therefore, act in isolation and do not help to achieve the process objective. The first set (group of tasks in blue color) of disconnected tasks is formed by "Determining group's characteristics, Defining prior knowledge, Applying characterization mechanisms, and Analyzing the prior knowledge", and the second set (group of tasks in yellow color) by the tasks that "Give feedback on the activity and Close the activity". Furthermore, in this view, it can be observed that the tasks with numbers 1, and 2 correspond to "Evaluate the problem resolution, and Evaluate the achievement of objectives", where their width exceeds the average with respect to the others, which allows identifying the possible existence of error-pattern-multipurpose, which refers to the fact that a task should focus on the achievement of a specific purpose, instead of generating work products that detract from the task that is the basic unit of work of the process.

View of the work products of the process model

To verify the process model with respect to the work products, AVISPA provides a view for this purpose. This view allows seeing the over-demanded work products (Camacho, Hurtado-Alegria, & Ruiz-Melenje, 2016). Figure 5.5 shows that the work products with numbers 1, 2, and 3 correspond to "List of objectives to be achieved in the activity, Activity problem with its information, and the List of each participant with their respective role", and that their height exceeds the average with respect to the others, which allowed identifying the existence of the error pattern in the over-demanded work products. In addition, in the upper part of the figure, there is an isolated subgraph, formed by the set of work products in green color, "Information on the results obtained in the activity and Lessons learned from the participants", this isolated graph allowed to identify the possible existence of the error pattern of independent subprojects. In Figure 5.6, the nodes also represent work products, but this view emphasizes nodes that may be useless, showing that the dark blue nodes identify the possible existence of the pattern of waste work products, which refers to work products that are neither deliverables nor inputs to any task.

View roles of the process model

In the role view, each node identifies a role and each of the lines between nodes specifies collaboration (Hurtado, Bastarrica , & Bergel, 2013). Figure 5.7 presents the results obtained when evaluating the fourth version of the process with respect to its roles, where most of the nodes do not collaborate with each other, which allows recognizing the presence of the Isolated Role error pattern (Camacho, Hurtado-Alegria, & Ruiz-Melenje, 2016), since as far as possible it is necessary to define roles that collaborate with each other (Hurtado , Lagos, Bergel, & Bastarrica, 2010).

5.3.6 Validation 5

The following case study aimed to validate whether the application of THUNDERS (version 5) in a problem-solving activity improved collaborative work. Each of the new elements of this version is specified below. This case study was developed in an educational context, in a collaborative activity to develop a problem applying data structure concepts, to students of Unicomfacauca - Colombia. To solve the problem, there were participants who used THUNDERS, and participants who did not use it, in order to determine the improvement of the collaborative work with the use of the proposed process. The following sections show in detail what was done to analyze the results of this case study.

5.3.6.1 New elements of version 5 of the process

Based on the results obtained in the validation of version 4 (by experts and AVISPA), some changes, corrections, and improvements were made, thus obtaining version 5 of the process. These new elements were:

- Phase names are changed. The design phase of the activity and its elements is named Beginning, the phase where the activity is executed and the shared understanding is validated is named Developing, and the phase where the resolution of the problem is validated, and the performance of the participants is evaluated is named Measuring.
- Corrected the English syntax in the name of the activities and tasks
- A new variability is assigned for each task, and for those tasks that are optional, the contexts and situations when they should be executed are defined.
- Task names are changed to make them clearer.
- Some tasks are repositioned to be executed as inputs to other tasks.
- Some assistance documents are improved in order to make them easier to use.
- Some task descriptions are better written to make them clearer.
- Task inputs and outputs are improved to improve the relationship between them.
- Relationships between process roles are analyzed and corrected.

5.3.6.2 Case study design

The case study is an empirical method that was used to analyze THUNDERS in its latest version and determine whether it ultimately improves collaborative work. For the design and implementation of this validation, we followed the case study method proposed by Runeson and Höst (2009). Case studies are, by definition, conducted in the real world seeking to analyze a phenomenon in a real context, but this is achieved at the expense of the level of control. This case study presents qualitative and quantitative data to achieve a better understanding of the phenomenon under study.

<u>Research question and objective</u>

The design of this case study was based on the research question: Does the application of the THUNDERS process in a problem-solving activity, with heterogeneous group formation, allow for the improvement of collaborative work? In this sense, the purpose of the case study was to investigate the improvement that THUNDERS, in its fifth version, generates in collaborative work, in the execution of a problem-solving activity, in this case in an academic context.

Selection of the Case Study

To carry out the case study, it was necessary to look for a context to prove that THUNDERS improves collaborative work, for this the academic context was chosen because it allows more time to analyze each element of the process and in the same way to have several participants who can use it with time available to apply the study. The type of case study according to the research perspective is positivist because it seeks to test the hypotheses regarding THUNDERS. This study is also holistic because the case is studied as a whole. The case study has a unit of analysis that corresponds to the resolution of a problem in the academic context of data structures

Case study context

The case study was conducted in a university environment considering two scenarios: a total of 60 students from the Corporación Universitaria Comfacauca - Unicomfacauca de Popayán Colombia participated. Where they were divided into two large groups, 30 students to execute the collaborative activity with the use of THUNDERS (UFT) and 30 students who served as contrast groups where they did not apply the process (UFWT). For the conformation of the UFT groups, the personality characteristics of the groups were selected, using the instrument provided as an assistance document "Instrument - Personality traits", which contains the Big five inventory-BFI test (Benet-Martínez & Oliver, 1998), which is a purely descriptive model of personality, evaluating each of the five factors or dimensions in the individuals. The objective of using this instrument is to have a scientifically accepted way of quantifying the personality traits of each participant. To identify the personality of the participants, they had to fill out the form and then proceed to analyze the results. With this, heterogeneous groups were formed (5 participants per group) using also the mechanism offered by the process called "Recommendations to organize the groups for the activity". On the other hand, the problem-solving activity, to be solved by all the participants (both UFT and UFWT) consisted that each group had to know initially the concepts of Stacks and Queues, to solve a problem of storage and data management of the products of a supermarket, choosing which was the best data structure to make an application in Java that would allow doing this information management making use of the restrictions of each structure.

Experiment hypothesis

Considering the objective of the case study, the following hypotheses were evaluated:

- THUNDERS improves the products obtained to solve the problem, as a result of executing the collaborative activity.
- THUNDERS improves the shared understanding of what the participants in the collaborative activity should do.
- THUNDERS improves the shared understanding of the results obtained at the end of the execution of the collaborative activity
- THUNDERS improves the performance of the participants in executing the collaborative activity

In order to refine the above hypotheses, the following specific hypotheses with their respective variables were raised (see Table 5.13):

	Hypothesis	**Variables**
Improvement in products obtained	H.1.1 Groups using the process get better problem-solving products	*Improvement in the products obtained from the resolution of the problem*: Represents the degree of improvement between groups that use the process and those that do not, in the problem-solving products. It is a comparison between the results obtained in the validation of the products obtained.
	H.1.2 Groups that use the process solve the problem completely and correctly	*Improved correct and complete resolution of the problem*: Represents the degree of improvement between the groups that use the process and those that do not, in the complete and correct solution of the problem. It is a comparison between the results obtained in the validation of the solution to the problem.
Improvement in initial shared understanding	H.2.1 Groups that use the process get better results of the shared understanding of what to do in the activity	*Improved in initial shared understanding*: Represents the degree of improvement between groups that use the process and those that do not, in the shared understanding of what they should do in the activity. It is a comparison between the results obtained in the validation of the initial shared understanding construction.
	H.2.2 Groups that use the process get a complete and correct shared understanding of what to do in the activity	*Improvement in the complete and correct construction of the initial shared understanding*: Represents the degree of improvement between the groups that use the process and those that do not, in the complete and correct shared understanding. It is a comparison between the results obtained in the validation of the correctness and completeness of the initial shared understanding.
Improvement in final shared understanding	H.3.1 Groups that use the process get better results of shared understanding about the results obtained in the activity	*Improvement in the final shared understanding*: Represents the degree of improvement between the groups that use the process and those that do not, in the shared understanding of the results obtained in the activity. It is a comparison between the results obtained in the validation of the final shared understanding construction.
	H.3.2 Groups that use the process obtain a complete and correct shared understanding of the results obtained in the activity	*Improvement in the complete and correct construction of the final shared understanding*: Represents the degree of improvement between the groups that use the process and those that do not, in the complete and correct shared understanding. It is a comparison between the results obtained in the validation of the correctness and completeness of the final shared understanding.
Improved performance of participants	H.4.1 Groups using the process obtain better individual performance in the execution of the collaborative activity	*Improved individual performance of participants*: Represents the degree of improvement between the groups that use the process and those that do not, in the individual performance of the participants. It is a comparison between the results obtained in the evaluation of the individual performance of the participants, considering aspects of participation, perspective-taking, social regulation, general aspects, and self-appraisal.
	H.4.2 Groups that use the process perform better as a group in the execution of the collaborative activity	*Improved group performance of the participants*: Represents the degree of improvement between the groups that use the process and those that do not, in the group performance of the participants. It is a comparison between the results obtained in the evaluation of the group performance of the participants, considering aspects of participation, collaboration, organization, coordination, responsibility, results, negotiation, and self-appraisal.

Table 5.13 Experiment specific hypothesis

Design of case study activities

In order to execute the case study, a set of activities were designed, which allowed carrying out all the necessary actions to obtain the expected results. These activities, with their expected duration and the instruments used, are presented in the following Table 5.14.

Experiment activity	Planned duration	Support instruments
For UFT		
Activity 1: Execution of the Beginning phase	1 hour	THUNDERS web publication is provided to guide each of the activities, tasks, and steps, which contains each of the assistance documents to execute these phases.
Activity 2: Execution of the Developing phase	3 hours	
Break	10 minutes	None.
Activity 3: Execution of the Measuring phase	1 hour	THUNDERS web publication is provided to guide each of the activities, tasks, and steps, which contains each of the assistance documents to execute this phase.
		TOTAL TIME: 5 hours 10 minutes
For UFWT		
Activity 1: Design of the collaborative activity	30 minutes	
Activity 2: Execution of the collaborative activity and measurement of shared understanding.	2 hours	The same mechanism used by the UFT groups is used to measure shared understanding.
Activity 3: Validation of the problem fulfillment, performance evaluation and end of the collaborative activity	1 hour	The same mechanism used by the UFT groups is used to validate the fulfillment of the problem and evaluate the performance of the participants.
		TOTAL TIME: 3 hours 30 minutes

Table 5.14 Design of experiment activities

5.3.6.3 Case study execution

For this case study, 64 people participated (60 students and four for the design of the activity) who assumed different roles during the application of the study. The UFT groups applied the elements defined in the process, and the person responsible for the corresponding designs selected those tasks, which in his opinion, were necessary for this context, executing the steps specified for these selected tasks. In this way, use was made of the tools and help documents provided for their support. For their part, the UFWT groups performed the same collaborative activity, to whom the topic was defined, and they made the design of the collaborative activity according to their consideration, with the formation of random groups, and simply among the groups, they gave solution to the activity without following the proposed process. These groups used the same mechanisms selected by the UFT groups for the measurement of the shared understanding (in both moments), validation of the solution to the problem, and performance evaluation, in order to obtain the data and make the respective comparisons, The following defines the activities of the case study with the time spent and the specific tasks that were applied (See Table 5.15Table 5.11).

Activity	Process tasks performed	UFT	Activity	UFWT	Estimated time
Activity 1	Plan the population characterization (Use the Instrument - Personality traits), Characterize the population that will participate	2 hours	Activity 1	1 hour	1 hour

	in the activity, Analyze the information obtained in the characterization, Monitor the tasks to define the population, Define the activity objectives, Describe the activity (The activity proposed by the process, "The three C", was selected), Define the activity success criteria, Detail the collaborative activity, Monitor the tasks to design the problem-solving activity, Organize the groups for the activity, Design the roles of the activity participants (Roles recommended by the process were used), Monitor the tasks to define the groups, Design the validation of the compliance with the problem (The assistance mechanism was selected), Design the validation of the shared understanding construction (The concept mapping mechanism was selected), Design the evaluation of the participants' performance (The assistance mechanisms were selected), Monitor the tasks to design the validation and evaluation methods.				
Activity 2	**First session**: Organize groups and assign roles, Monitor the task to form the groups, Socialize the problem to be solved, Socialize collaborative activity, Monitor the task to describe the problem-solving activity, Understand collaborative activity individually and in groups. **Second session**: Validate the initial shared understanding, Select the problem solution to be implemented, Implement the problem solution, Validate the problem solution, Validate the final shared understanding, Monitor the task to develop collaborative activity.	Two sessions were held, each lasting 1 hours. Total 2 hours.	Activity 2	1 hour 10 minutes	3 hours
Break	--	5 minutes	Break	5 minutes	10 minutes
Activity 3	Validate compliance with the problem, Validate compliance with the problem, Evaluate the individual and group performance, Monitor the tasks to evaluate the participants' performance, Provide the feedback to the participants, End the activity, Monitor the tasks to close the activity.	1 hour	Activity 3	45 minutes	1 hour
	TOTAL TIME	5 hours 5 minutes		3 hours	4 hours 10 minutes

Table 5.15 Time spent on each activity and process tasks performed

5.3.6.4 Results obtained

After the execution of the activities designed for the case study, different results were generated, those obtained from observation and statistical calculations to define the improvement or not of the process. From the observation, it was identified that each of the people who applied the process, could execute in detail each of the required tasks with adequate support, however, it is a fairly high number of tasks and documentation, which generates a high load for each person and the need for sufficient time to execute them. On the other hand, the study used a control group that did not use the process (UFWT) and a group that did (UFT), to ensure that the differences in the final results were not only observed but statistically significant, and Student's t-distribution was used to validate the hypotheses.

For this case study, the Student's t-test type was applied, b) and c), using the function offered by the Excel office automation package for the calculation of this test. The values used to perform this calculation were (See Table 5.16):

	Type b) and c) t-tests
Reliability level	95%
Significance level	5%
Observations or cases	6 (UFT), 6 (UFWT)
Critical value in	Two tailed
Degrees of freedom	10

Table 5.16 Values used for T-tests

For this study, the hypotheses for Fisher's test were considered as in the previous experiment.

- H_0 = variances are equal
- H_a = variances are different

And in the types of tests, the acceptance or rejection of the null hypothesis was considered.

- If the P-value or F-value <= significance level, the null hypothesis is rejected
- If the P-value or F-value > significance level, the null hypothesis is accepted

Considering the hypotheses, after applying the statistical analysis, the following results were generated and are shown in Table 5.17. For all variables, after applying the Fisher test, the Student's t-test type b) was selected.

Hypothesis	Values type	Results	Accepted hypothesis
H.1.1	Scores between 0 and 5	F-Value= 0.614; T-value =-3.152; P (0,010)	**H.1.1a**= There is a statistically significant difference in the mean scores obtained in the validation of the products obtained between UFT and UFWT participants.
H.1.2	Very well solved (5) – Very poorly solved (1)	F-Value= 0.558; T-value = -4.492; P (0.0012)	**H.1.2a** = There is a statistically significant difference in the mean of the results obtained in the validation of the solution to the problem between UFT and UFWT participants.
H.2.1	High (3) – Low (1)	F-Value= 0.562; T-value = -5.320; P (0.00034)	**H.2.1a** = There is a statistically significant difference in the mean scores obtained in the validation of the initial shared understanding construction between UFT and UFWT participants
H.2.2	Very correct and complete (5) - Very little correct and complete (1)	F-Value= 0.688; T-value = -4.602; P (0.00098)	**H.2.2a** = There is a statistically significant difference in the mean scores obtained in the validation of the correctness and completeness of the initial shared understanding, between UFT and UFWT participants.
H.3.1	High (3) – Low (1)	F-Value= 0.643; T-value = -4.172; P (0.0019)	**H.3.1a** = There is a statistically significant difference in the mean of the results obtained in the validation of the final shared understanding construction, between UFT and UFWT participants
H.3.2	Very correct and complete (5) - Very little correct and complete (1)	F-Value= 0.257; T-value = -4.113; P (0.0021)	**H.3.2a** = There is a statistically significant difference in the mean scores obtained in the validation of the correctness and completeness of the final shared understanding, between UFT and UFWT participants.
H.4.1	Excellent (5) – Very wrong (1)	F-Value = 0.361; T-value = -4.237; P(0.0017)	**H.4.1a** = There is a statistically significant difference in the mean of the results obtained in the evaluation of the individual performance of the participants, considering aspects of participation, perspective-taking, social regulation, general aspects, and self-appraisal, between UFT and UFWT participants.

H.4.2	Excellent (5) – Very wrong (1)	F-Value = 0.154; T-value = -3.697; P (0.0041)	**H.4.2a** = There is a statistically significant difference in the mean of the results obtained in the evaluation of the group performance of the participants, considering aspects of participation, collaboration, organization, coordination, responsibility, results, negotiation, and self-appraisal.

Table 5.17 Results for each specific hypothesis

Discussion of results

According to the observation, during the realization of the activity, it was identified that the UFT participants, having a detailed guide of what to do, are focused on achieving the objectives of the collaborative activity and thus obtain better results of collaboration and the solution to the problem, without looking for what and how to do it. While the UFWT participants, by doing everything without a guide, depend a lot on their experience and previous knowledge both in the design of collaborative activities and in the execution, which influences the results obtained and makes them disoriented in what they should do. It was also observed that the process still needs to be made lighter, especially for activities that are simpler to carry out and require less documentation, since the process is still very extensive and requires a lot of time for its application. It was also identified the need to have a software application to guide the completion of each document of the process, in order to have the information more organized and to guide more easily the execution of each task and specific step of the process.

From the statistical results it was possible to determine that:

- Hypothesis H.1.1a can be accepted. Thus, it can be said that there is a significant difference between the mean scores obtained in the validation of the products obtained between the participants of the UFT and the UFWT. According to the above, it can be inferred that the use of the process improved the products obtained as a result of the execution of the collaborative activity.
- Hypothesis H.1.2a can be accepted. Thus, it can be said that there is a significant difference between the mean of the results obtained in the validation of the solution of the problem between the UFT and UFWT participants. According to the above, it can be inferred that the use of the process improved the problem solving as a result of the execution of the collaborative activity.
- Hypothesis H.2.1a can be accepted. Thus, it can be said that there is a significant difference between the mean scores obtained in the validation of the initial shared understanding construct between UFT and UFWT participants. According to the above, it can be inferred that the use of the process improved the construction of initial shared understanding among the participants.

- Hypothesis H.2.2a can be accepted. Thus, it can be said that there is a significant difference between the mean scores obtained in the validation of the correctness and completeness of the initial shared understanding between the UFT and UFWT participants. According to the above, it can be inferred that the use of the process improved the initial shared understanding, considering that a correct and complete initial understanding is obtained among the participants.
- Hypothesis H.3.1a can be accepted. Thus, it can be said that there is a significant difference between the mean scores obtained in the validation of the final shared understanding construct between UFT and UFWT participants. According to the above, it can be inferred that the use of the process improved the construction of the final shared understanding among the participants.
- Hypothesis H.3.2a can be accepted. Thus, it can be said that there is a significant difference between the mean scores obtained in the validation of the correctness and completeness of the final shared understanding between the UFT and UFWT participants. According to the above, it can be inferred that the use of the process improved the final shared understanding, considering that a correct and complete final understanding is obtained among the participants.
- Hypothesis H.4.1a can be accepted. Thus, it can be said that there is a significant difference between the results obtained in the evaluation of the individual performance of the participants, considering aspects of participation, perspective-taking, social regulation, general aspects, and self-appraisal, between the participants of the UFT and the UFWT. According to the above, it can be inferred that the use of the process improved the individual performance of the participants from different aspects, which allows obtaining better processes and results.
- Hypothesis H.4.2a can be accepted. Thus, it can be said that there is a significant difference between the results obtained in the evaluation of the group performance of the participants, considering aspects of participation, collaboration, organization, coordination, responsibility, results, negotiation, and self-appraisal. According to the above, it can be inferred that the use of the process improved the group performance of the participants from different aspects, which allows for greater elements for better collaboration.

In this sense, with the specific hypotheses accepted, the general hypotheses of the case study can be accepted, concluding that THUNDERS improves the products obtained to solve the problem as a result of the execution of the collaborative activity, improves the shared understanding of what the participants must do in the collaborative activity, improves the shared understanding of the results obtained at the end of the execution of the collaborative activity, and finally, improves the performance of the participants in the execution of the collaborative activity. With these hypotheses accepted, it is clear to determine that the process proposed here, THUNDERS, in its fifth version, improves collaborative work from different aspects, a process that contains a set of elements to design, execute and validate a collaborative activity, based mainly on the construction, monitoring and assistance of shared understanding as a tool to improve communication among participants, which showed that with better communication there is a greater willingness to work, to contribute, to participate, obtaining greater collaboration and therefore as a consequence, better results are obtained and the proposed objectives are met.

For evidence of what was done in this case study see *Annex 12.*

Chapter 6

CONCLUSIONS

6.1 Overview

From the research conducted to develop this project, it was possible to determine the main problem of collaborative work, which refers to the difficulty of building a true collaboration, which led to search for its main causes. The lack of assertive and adequate communication among the participants of the groups was identified as one of the main causes that would allow generating an adequate collaboration. In this sense, when considering factors that influence communication to obtain the expected results in collaborative activities in different contexts, and correct and adequate performance, the benefits of shared understanding were analyzed. Considering this, this research defined a process that through the different elements that compose it, both its conceptual level (which defines what and how to design, execute and validate a collaborative activity) and its technological level (which are those elements of the process that allow supporting the execution of the different phases, activities, tasks, and steps) will seek to build, monitor and assist shared understanding in collaborative problem-solving activities, with heterogeneous training. Process called THUNDERS, which after its construction using the Situational Method Engineering (SME), was validated in its five versions, making use of different mechanisms, reaching the main conclusion that this process does improve the collaborative process. For this reason, this chapter brings together the conclusions obtained during the project and their respective contributions. In addition to determining the limitations of the project, and the future work that remains to be done for subsequent projects in this same area of research. Finally, the different research activities that were carried out throughout the training and research process are shown. The sections of this chapter are summarized in the following image (See Figure 6.1).

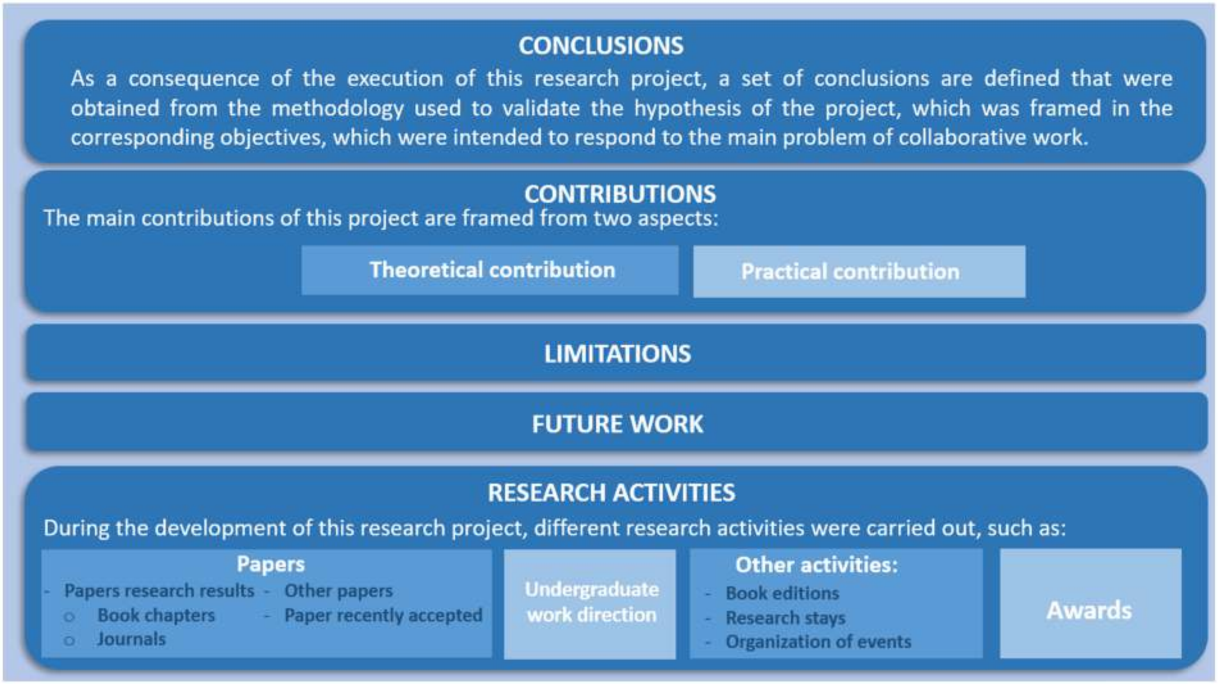


Figure 6.1 Sections presented in this chapter

6.2 Conclusions

According to the planning, execution, and analysis of the results obtained in the systematic review of the literature and related works on the different topics that were addressed in this research project, it can be determined that there are research works for the construction and measurement of shared understanding in different collaborative contexts, which show the importance and benefits that can be obtained by achieving its correct construction. However, analyzing the focus of these works, they have been diverse, some aimed at measuring shared understanding, mostly from the aspect of perception, and others with tools that are not quick and easy to apply, have also focused on showing its benefits and determining that its construction is something obvious that happens in collaborative activities, without specifying how to achieve it, and that despite being obvious it often does not happen. On the other hand, research on collaborative work shows the focus that most of them have, being the analysis of the interactions between participants and the definition of technological tools to execute collaborative activities; without analyzing that collaboration is not achieved many times, and that it is necessary to analyze the cognitive motives that happen in the participants that influence to a great extent in obtaining a better collaboration. That is why, analyzing the benefits and existing needs to achieve shared understanding among participants, both of what to do in the activity and what is finally done, this research project defines a process to support all phases that should have the collaborative work, seeking to achieve collaboration as a result of building shared understanding and thus generate better communication, through a systematic process that defines what and how to execute it, and thus solve the problem posed in the collaborative activity.

The THUNDERS process presented in this research has been built using the Situational Method Engineering (SME) approach, where initially, the collaborative learning approaches proposed in previous research were studied, considering the elements proposed by each one and their context. With the latest version of the specified approach to collaborative learning analyzed and applied in an exploratory case study, opportunities for improvement were identified, and subsequently, the method engineering through each proposed activity, allowed to identify the requirements to be met by the process in the context of collaborative work, selecting the method components through the analysis of the different existing approaches and the identified needs, assembling them with the formalization of the process and subsequently validating the versions of the process generated. As a final result, the specification of a process in SPEM 2.0 is obtained, at two levels, conceptual (defines the elements and how to execute the collaborative process) and technological (support tools for such execution), to design, execute and validate a collaborative problem-solving activity, with heterogeneous group formation, which provides a sequence of phases, activities, tasks, and steps, well defined and a clear specification of the work products, including the description of the different roles of both the execution of the process and those necessary in the collaborative activity. In addition to being a process that is based on the construction of shared understanding in each of its elements, it also provides monitoring and assistance elements that allow supporting the application of the process and achieving the proposed objectives and the solution of the problem collaboratively. The process provides the possibility of executing different tasks from the perspective, experience, and knowledge of the role in charge of executing the specific task, and, on the other hand, it provides a set of assistance documents, which, if the role wishes, chooses those documents to guide the execution of those tasks with formats and elements necessary to comply with what is required and thus ensure the construction of shared understanding and the solution to the problem.

Achieving collaboration is not an easy task, since there are many factors involved, and many of them have been previously analyzed by different authors, and even so, it is not easy to achieve the collaboration of all participants. However, those cognitive factors of the participants have not been analyzed much, and in this sense, in this research, the shared understanding is analyzed as the basis for assertive and adequate communication, being this a key element for the participants to collaborate in achieving the common goal. Thus, establishing a common language and coordination among the participants about what they should do in the activity, that is, that everyone understands correctly and in the same way what they should achieve, will encourage the participants to achieve the objectives together, and provide their collaboration to achieve it. It is also necessary that all participants have a common understanding about the solution to the problem obtained, as this will make the results better and that everyone agrees and provides their opinions and appropriate contributions. For this reason, the process proposed here, considering the construction of the shared understanding in these two moments and their respective measurement, in order to carry out the pertinent actions in case they are required to direct these understandings and obtain better results. In addition to providing the appropriate elements to build it in a guided manner, with which it was possible to identify that designing all the elements of a collaborative activity that takes into account all that is necessary for its subsequent execution, is of vital importance for such execution to develop as expected, to obtain the results, to achieve the objectives and to build what is necessary.

In this research, a set of empirical experiences was carried out at different stages of the research and in different contexts, which allowed building the process in an iterative and incremental manner, from the definition of a design, execution, and subsequent analysis of the results obtained in each of the studies, using a set of previously defined hypotheses. The quantitative and qualitative information obtained from each of the studies, allowed to improve the detection of problems and deficiencies in the process, analyzing in parallel the conceptual basis compiled through the research available in the literature. The different contexts where the process was applied was one of the advantages for the analysis; although not all possible contexts were covered, they allowed considering different aspects and enriching the formulation of the process. In the validations carried out, it was possible to accept hypotheses among which it was determined that the process in its different versions is feasible, useful, complete, and finally improves collaborative work. However, also in the validation of the latest version, it was determined that the process continues to generate a lot of cognitive load, despite the addition of variability in the tasks (defining mandatory tasks and those whose execution depends on established conditions) and the inclusion in each assistance document of the obligatory or not of the completion of its items, and despite this, it continues to be a process that requires generating a lot of documentation and a lot of time available for its application. In addition to being a process that requires a software tool to support the management of the documentation generated, because, although the web deployment generated by EPFC allows the management of the process elements, it does not allow its completion and the management of all the documentation generated.

Considering all the above conclusions, it is possible to confirm the hypothesis defined at the beginning of this research, which refers to: A process for the design, execution, and validation of collaborative activities based on elements that allow the construction, monitoring, and assistance of shared understanding improves computer-supported collaborative work. In this sense, THUNDERS offers the necessary elements to construct, monitor, and assist shared understanding, in the phases of collaborative work, in such a way that its application in the contexts that were the object of study, improved such collaborative work, considering different aspects, such as improvement in participation, collaboration, organization, coordination, responsibility, results, and negotiation.

6.3 Contributions

According to some authors (Bittner & Leimeister, 2014) (Gomes & Tzortzopoulos, 2018) (Chen, Linh Nguyen, & Hac, 2021) there is very little research on what are the elements that enable the construction of shared understanding, and what actions should be performed for such construction. Moreover, in activities where there are participants who must work together to achieve a common goal, achieving this understanding and coordination seems an intuitive and obvious action, however, there is a lack of support for its achievement and its measurement in time, to determine corrective actions and to obtain better results and greater collaboration to avoid rework and non-achievement of the problem solution. Since lack of shared understanding about the activity can hinder the progress of the team and can negatively influence the outcome (Hey, Joyce , & Beckman, 2007). This is due to communication failures that do not allow adequate collaboration among participants to achieve problem resolution (Kauffmann & Carmi, 2020). Therefore, shared understanding is a facilitator of collaboration and, as a consequence, improves collaborative work. (Smart P. , 2011). In this sense, and based on the research conducted, the contributions of this project are:

6.3.1 Theorical contribution

- To make evident the importance and benefits of shared understanding, as well as the need to improve and contribute to the development of empirical evidence in the construction and measurement of shared understanding in collaborative activities, through the definition and structuring of the state of the art.
- Critical analysis of the related works found, where it is shown that in the range of period analyzed, there is no empirical evidence that proposes and validates a process for the construction of shared understanding in problem-solving activities.
- Systematic literature review, where existing approaches were identified, and aspects related to the established research questions were analyzed. The results obtained allowed guiding the definition of elements of the process and can be used for future research.
- Characterization and materialization of a process in which different elements of the process are conceptualized, related, collected, and proposed, such as: instruments,

components, and tools involved and necessary in the construction of shared understanding in the design, execution, and validation of a problem-solving activity with heterogeneous group formation.

6.3.2 Practical contribution

- THUNDERS was defined after the review and study of existing approaches and following the guidelines of the engineering method, building a formal and enriched process with phases, activities, tasks, steps, workflows, guidelines, work products, and roles, which supports the construction of shared understanding in problem-solving activities.
- Contribute to the adoption of the process in computer-supported collaborative work that achieves improvement through the construction of shared understanding in problem-solving activities.
- With the application of the process, it is sought that any problem-solving activity in a collaborative work environment, through the monitoring and assistance provided by the mentioned process, achieves shared understanding, so that the collaborative activity generates better results, and the objective of the activity is achieved.
- To provide the community with empirical evidence on the construction of shared understanding, its measurement, and strategies to maintain it during the execution of a collaborative activity, in the context of requirements engineering and education.
- Provide planning, execution, and analysis of the results of experiments, an exploratory study, a case study, and expert validation to examine and contrast the approaches found in the theoretical studies with the results obtained in practice. The observations made and the results obtained not only provided findings that allowed for the improvement of the proposed process, but also a set of useful information to be considered for future work in this area of research.

6.4 Limitations

- THUNDERS offers a technological level, where elements are considered that allow the support of the execution of the process, using a set of method content, and elements of the process itself, without having a software tool to guide this application more easily.
- There was a very small number of samples for the calculations where the Student's t-test was used, so it is not possible to ensure a representative distribution of the population, however, the validations presented here were aimed at identifying improvements and corrections to the process, which was achieved with the selected samples.
- Some measurements in the validations presented were made through the self-appraisal of the participants, which can generate subjective responses; however, it was also

sought to have an observer who could analyze the actions performed and thus give appreciations to the different studies presented.

- The variability of THUNDERS was defined to choose specific tasks depending on the contexts, which could only be validated in two main contexts, requirements engineering, and education.

6.5 Future work

According to the project developed here, there are aspects that have not yet been considered and that allow us to continue with research in this line. In this sense, some future works that are proposed are:

- It is expected to improve the definition of the different elements that make up THUNDERS, through more empirical evidence, where the process can be subject to further validation in other contexts and allow its subsequent improvement.
- To provide computational support for the execution and monitoring of the process and the actions that are carried out in the collaborative activity, so that each of the foreseen steps can be executed with computer support and thus facilitate the observation of the information, the support of the participants and the management of the information. Incorporating an automatic analysis of the data obtained, for the support of the different roles, both of the process and of the collaborative activity.
- Generating more user-friendly versions of the process depending on the type of collaborative activities and the context, i.e., a version for those activities that are simpler to execute and do not require all the rigor and documentation provided by the process, or more complex versions of the process for those activities that do require it.
- Incorporate other elements to measure the shared understanding in a way that with computational support allows the execution of actions in real-time to improve and correct it in the indicated time.
- It is necessary to investigate in greater depth the level of heterogeneity that directly influences the construction of shared understanding, determining which are the best characteristics to be considered in a group so that such understanding is constructed correctly.

6.6 Research activities

As a result of this work, different types of activities supported the research conducted here, from training in the field of research, such as activities to achieve the objectives proposed here. Among these activities are:

6.6.1 Papers

6.6.1.1 Papers research results

Specifically, papers were generated as a result of the research conducted here, which are as follows:

Book chapter

- Conceptos base de colaboración. Vanessa Agredo-Delgado, Pablo H. Ruiz. *Name of the book: Perspectivas en la interacción humano tecnología*. Editorial: HCI-COLLAB. 2022.
- Trabajo colaborativo. Vanessa Agredo-Delgado, Cesar A. Collazos. *Name of the book: Perspectivas en la interacción humano tecnología*. Editorial: HCI-COLLAB. 2022.
- Validating the Shared Understanding Construction in Computer Supported Collaborative Work in a Problem-Solving Activity. Vanessa Agredo-Delgado, Pablo H. Ruiz, Alicia Mon, Cesar A. Collazos, Fernando Moreira and Habib M. Fardoun. *Name of the book: Trends and Innovations in Information Systems and Technologies*. Volume 3. 2020.
- Towards a process definition for the shared understanding construction in Computer-Supported Collaborative Work. Vanessa Agredo-Delgado, Pablo H. Ruiz, Alicia Mon, Cesar A. Collazos and Habib M. Fardoun. 2020. *Name of the book: HCI-COLLAB 2020: Human-Computer Interaction*, pages: 263 – 274. Editorial: Springer. 2020.
- A reformation proposal of the Process phase in the computer-supported collaborative learning. Vanessa Agredo-Delgado, Pablo H. Ruiz, Cesar A. Collazos and Habib M. Fardoun. *Name of the book: HCI-COLLAB 2019: Human-Computer Interaction*, pages: 17-29. Editorial: Springer. 2019.
- Refining the Process phase in the computer supported collaborative learning. Vanessa Agredo Delgado, Pablo H. Ruiz, Cesar A. Collazos, Habib M. Fardoun. *Name of the book: Research and development in Learning Environments*. ISBN BUAP: 978-607-525-665-8. ISBN UA Journals: 978-84-949828-4-2. Editorial Benemérita Universidad Autónoma de Puebla. 2019.
- Towards a Framework Definition to Increase Collaboration and Achieve Group Cognition. Vanessa Agredo-Delgado, Pablo H. Ruiz, Cesar A. Collazos, Daniyal M. Alghazzawi and Habib M. Fardoun. *Name of the book: Learning and Collaboration Technologies. Design, Development and Technological Innovation*, pages: 337-349. Editorial: Springer. 2018.
- Framework for increasing collaboration and achieving group cognition. Vanessa Agredo Delgado, Cesar Collazos. *Name of the book: Ingeniería colaborativa aplicaciones y usos desde la perspectiva de la Interacción Humano Computador*, pages: 419 - 424. Volume: 2. Tendencias y aplicaciones. Editorial: Bonaventuriana, 2019, Universidad de San Buenaventura, Cali. 2018.

- Software tool to support the improvement of the collaborative learning process. Vanessa Agredo Delgado, Pablo H. Ruiz, Cesar A. Collazos, Habib M. Fardoun and Amin Y. Noaman. *Name of the book: Advances in Computing*, pages: 442-454. Editorial: Springer. 2017.
- Collaboration increases through monitoring and evaluation mechanisms of the collaborative learning process. Vanessa Agredo Delgado, Cesar A. Collazos, Habib M. Fardoun and Nehme Safa. *Name of the book: Social Computing and Social Media. Applications and Analytics*, pages: 20-31. Editorial: Springer. 2017.

Journal

- An Exploratory Study on the Validation of THUNDERS: A Process to Achieve Shared Understanding in Problem-Solving Activities. Vanessa Agredo-Delgado, Pablo H. Ruiz, Cesar A. Collazos and Fernando Moreira. *Informatics Journal*. Volume 9. No 39. 2022.
- Applying a process for the shared understanding construction in computer-supported collaborative work: An experiment. Vanessa Agredo-Delgado, Pablo H. Ruiz, Alicia Mon, Cesar A. Collazos, Fernando Moreira and Habib M. Fardoun. *Computational and Mathematical Organization Theory Journal*. 2021.
- Methodological guidelines catalog to support the collaborative learning process. Vanessa Agredo-Delgado, Pablo Ruiz Melenje, Cesar A. Collazos, Fernando Moreira, Habib M. Fardoune. *Education in the Knowledge Society Journal*. No. 21. 2020.
- Aplicando AGILE SPI – PROCESS para la construcción de mecanismos de monitoreo, evaluación y mejora del proceso de aprendizaje colaborativo. Vanessa Agredo Delgado, Pablo Ruiz, Cesar A. Collazos, Patricia Paderewski. *Gerencia tecnología informática GTI Journal*, Volume 15, No. 43. 2017.
- Aplicación del procedimiento formal definido para evaluar, monitorear y mejorar el proceso de aprendizaje colaborativo en su etapa de proceso mediante la creación de mecanismos. Vanessa Agredo Delgado, Cesar A. Collazos, Patricia Paderewski. *I+T+C - Investigación, Tecnología y Ciencia Unicomfacauca Journal*, Volume 1, No 10. 2016.
- Definición de mecanismos para evaluar, monitorear y mejorar el proceso de aprendizaje colaborativo, Vanessa Agredo Delgado, Cesar A. Collazos, Patricia Paderewski. *Tecnología Educativa CONAIC Journal*, Volume 3, No. 3. 2016.
- Definición de mecanismos para monitorear, evaluar y mejorar el proceso de aprendizaje colaborativo, Vanessa Agredo, César A. Collazos, Patricia Paderewski, Revista Colombiana de Computación – RCC, Volume 17 No. 1. 2016.
- Estudio de caso sobre mecanismos para evaluar, monitorear y mejorar el proceso de aprendizaje colaborativo, Vanessa Agredo Delgado, Cesar A. Collazos, Patricia Paderewski Rodríguez, *Campus Virtuales Journal*, Volume V, No. 01. 2016.

6.6.1.2 Other papers

In addition, as a result of the direction of graduate work and support for other research, the following papers were produced:

- Dealing with Uncertainties in IT Solutions for Agriculture. Leandro Antonelli, Cesar Collazos, Pascale Zarate, Vanessa Agredo Delgado, Guy Camilleri, Alejandro Fernández, Jorge E. Hernández and Diego Torres. *Name of the book: Agriculture Value Chain - Challenges and Trends in Academia and Industry: RUC-APS Volume 2*. Springer Book. 2022.
- Proposal of usability guidelines for the design of mobile applications in the rehabilitation of children with disabilities in working memory and verbal comprehension. Hernán David Montilla, Brayan Alejandro Chilito, Pablo H. Ruiz and Vanessa Agredo-Delgado. *Name of the book: Proceedings of the VII Iberoamerican Conference on Human Computer Interaction*. Editorial: CEUR. Volume 3070. 2021.
- A Scoping Definition Experiment in Software Process Lines. Pablo H. Ruiz, Vanessa Agredo-Delgado, Alicia Mon, Cesar A. Collazos, Fernando Moreira and Julio A. Hurtado. *Name of the book: Trends and Applications in Information Systems and Technologies*. Volume 4. 2021.
- Towards to usability guidelines construction for the design of interactive mobile applications for learning mathematics. Carlos Andrés Casas Domínguez, David Oidor Mina, Vanessa Agredo-Delgado, Pablo H. Ruiz and Deema M. AlSekait. Name of the book: HCI-COLLAB 2020: Human-Computer Interaction, pages: 275 – 284. Editorial: Springer. 2020.
- Structure of a guide for usability evaluation in virtual learning environments. Vanessa Agredo-Delgado, Juan David Pinto-Corredor, Cesar A. Collazos, Pablo H. Ruiz and Habib M. Fardoun. Name of the book: HCI-COLLAB 2019: Human-Computer Interaction, pages: 356 – 368. Editorial: Springer. 2019.
- A Usability Evaluation Guide in Virtual Learning Environments. Juan David Pinto Corredor, Vanessa Agredo Delgado, Pablo H. Ruiz, Cesar A. Collazos, Habib M. Fardoun. *Name of the book: Research and development in Learning Environments*. ISBN BUAP: 978-607-525-665-8. ISBN UA Journals: 978-84-949828-4-2. Editorial Benemérita Universidad Autónoma de Puebla. 2019.
- Interactive System Design. Cesar Collazos, Sandra Cano y Vanessa Agredo. *Name of the book: I Jornada Latinoamericana de Atualização em Informática (JoLAI_CLEI_LACLO)*. Chapter 7, pages: 151 – 168. Editorial: Universidad Mackenzie. 2018.
- Designing Collaborative Strategies Supporting Literacy Skills in Children with Cochlear Implants Using Serious Games. Sandra Cano, César A. Collazos, Leandro Flórez

Aristizabal, Fernando Moreira, Victor M. Peñeñory and Vanessa Agredo. *Name of the book: Trends and Advances in Information Systems and Technologies*, pages: 1317 - 1326. Volume 2, Editorial: Springer. 2018.

- Hacia la creación de una guía para la evaluación de la usabilidad en entornos virtuales de aprendizaje. Juan David Pinto, Vanessa Agredo Delgado, Cesar Collazos. *Name of the book: Ingeniería colaborativa aplicaciones y usos desde la perspectiva de la Interacción Humano Computador*, pages: 468 - 477 Volumen: 2. Tendencias y aplicaciones. Editorial: Bonaventuriana, 2019, Universidad de San Buenaventura, Cali. 2018.

Journal:

- The initial process of creating a guide to evaluate the usability in Virtual Learning Environments. Juan David Pinto-Corredor, Vanessa Agredo-Delgado, Pablo H. Ruiz, Cesar A. Collazos. *Avances: Investigación En Ingeniería Journal*, Volume: 18, No. 1. 2021.
- Propuesta de lineamientos de usabilidad para el diseño de interfaces en aplicaciones interactivas móviles para el aprendizaje de matemáticas en niños entre 6 y 7 años. Carlos Andrés Casas Domínguez, David Oidor Mina, Vanessa Agredo-Delgado y Pablo H. Ruiz Melenje. *Campus Virtuales Journal*. ISBN 978-84-949828-6-6. 2019.
- Construyendo una guía para la evaluación de la usabilidad en EVAs. Juan d. Pinto Corredor, Vanessa Agredo Delgado, César A. Collazos. *Campus virtuales Journal*. Volume 7, No. 2. 2019.
- A canonical software process family based on the Unified Process. Pablo H. Ruiz, Vanessa Agredo-Delgado, Marta Cecilia Camacho, Julio A. Hurtado. *Scientia et technica Universidad Tecnológica de Pereira Journal*, Volume 23, No. 3. 2018.

6.6.1.3 Paper recently accepted

- A strategy for building shared understanding in requirements engineering activities. Vanessa Agredo-Delgado, Pablo H. Ruiz, Luis E. Garzon and Cesar A. Collazos. *Sent to: Decisioning 2022: Collaboration in knowledge discovery and decision making: Applications to sustainable*.
- Hacia la construcción de un proceso de trabajo colaborativo para la elicitación de requisitos basado en entendimiento compartido. Valentina Vergara-Realpe, Jesús David Perea, Vanessa Agredo-Delgado, Pablo H. Ruiz and Cesar A. Collazos. *Sent to: Decisioning 2022: Collaboration in knowledge discovery and decision making: Applications to sustainable*.

- A process to improve Collaborative Work through shared understanding in problem-solving activities. Vanessa Agredo-Delgado and Cesar A. Collazos. Sent to: PhD Symposium: *Decisioning 2022: Collaboration in knowledge discovery and decision making: Applications to sustainable*.

6.6.2 Undergraduate work direction

- Name: Evaluación de usabilidad en entornos virtuales de aprendizaje para adultos mayores. Magister student: Juan David Pinto. University: Universidad del Cauca. In progress.
- Name: Una estrategia de trabajo colaborativo basado en la construcción de entendimiento compartido aplicado en la ingeniería de requerimientos. undergraduate student: Jesús David Perea. University: Unicomfacauca. In progress.
- Name: Lineamientos de usabilidad para el diseño de interfaces de aplicaciones móviles interactivas en la rehabilitación de niños con discapacidad cognitiva. Undergraduate student: Brayan Chilito and David Ojeda. University: Unicomfacauca. In progress.
- Name: Lineamentos de usabilidad para el diseño de interfaces en aplicaciones móviles interactivas para el aprendizaje de las matemáticas. Undergraduate student: Carlos Casas and David Oidor. University: Unicomfacauca. Presentation of the thesis: 31 May 2020.
- Name: Combinación de métodos para la evaluación de la usabilidad en entornos virtuales de aprendizaje. Undergraduate student: Juan David Pinto. University: Universidad del Cauca. Presentation of the thesis: 31 January 2019.

6.6.3 Other activities

Book editions

- Proceedings of the VII Iberoamerican Conference on Human Computer Interaction. Editorial CEUR. ISSN: 1613-0073. 2021
- Proceedings of the VII Iberoamerican Conference on Human Computer Interaction. HCI Collab 2021. Human-Computer Interaction, Editorial: Springer. eBook ISBN: 978-3-030-92325-9. 2021.
- Proceedings of the VI Iberoamerican Conference on Human Computer Interaction HCI Collab 2020. Human-Computer Interaction, Editorial: Springer. eBook ISBN: 978-3-030-66919-5. 2020.
- Proceedings of the V Iberoamerican Conference on Human Computer Interaction. HCI Collab 2019. Human-Computer Interaction, Editorial: Springer. eBook ISBN: 978-3-030-37386-3. 2019.

- Proceedings of the IV Iberoamerican Conference on Human Computer Interaction. HCI Collab 2018. Human-Computer Interaction, Editorial: Springer. eBook ISBN: 978-3-030-05270-6. 2018.

Research stays

- Universidad Nacional de la Plata. La Plata, Argentina. April 9 to May 9, 2022
- Universidad de Castilla la Mancha. Albacete, Spain. November 27 to December 27, 2021
- University of Applied Science. Bottrop, Germany. November 24 - 25, 2021.
- Universität Duisburg-Essen. Duisburg, Germany. November 23, 2021.
- Technischen Universitat Darmstadt. Darmstadt, Germany. November 19, 2021.
- Universidad de Castilla la Mancha. Ciudad Real, Spain. September 26 to November 26, 2021
- Universidad Nacional de la Plata. La Plata, Argentina. September 9 to November 9, 2018
- Universidad Nacional de la Matanza. Buenos Aires, Argentina. September 10 to November 8, 2018

Organization of events

- Event organizer *III, IV, V, VI, VII, VIII Jornadas Iberoamericanas Interacción Humano Computador*.
- Event organizer *Decisioning 2022: Collaboration in knowledge discovery and decision making: Applications to sustainable agriculture 2022.*

6.6.4 Awards

- Winner of scholarship for study trips and internships in Germany for groups of Colombian students. Awarded by: Deustscher Akademischer Austauschdienst (DAAD). Date: November 2021.
- *Award to the best Doctoral Symposium paper*. Awarded by: Doctorado en Ciencias de la Electrónica - Universidad del Cauca. Date: December 2021.
- *Outstanding project in the area of data, information and knowledge at the 15th Colombian Congress of Computing*. Awarded by: Sociedad Colombiana de Computación. Date: October 2020.
- *Recognition for research production*. Awarded by: Unicomfacauca. Date: August 2020.
- *Award for the best Doctoral Symposium paper at the 14th Colombian Congress of Computing*. Awarded by: Universidad Cesmag. Date: September 2019.
- *Recipient of the call for National Doctorates 2017 - # 785*. Awarded by: Ministerio de Ciencia, Tecnología e Innovación – Colciencias. Date: January 2018.

REFERENCES

Abraham, J., Kannampallil, T., Srinivasan, V., Galanter, W., Tagney, G., & Cohen, T. (2017). Measuring content overlap during handoff communication using distributional semantics: an exploratory study. *Journal of Biomedical Informatics*, 132-144.

Acuña, S. T., & Ferré, X. (2001). *World Multiconference on Systemics, Cybernetics and Informatics, ISAS-SCIs 2001, Orlando, Florida, USA , I: Information Systems Development*.

Agredo Delgado, V., Collazos, C., & Paderewski, P. (2016). Descripción formal de mecanismos para evaluar, monitorear y mejorar el proceso de aprendizaje colaborativo en su etapa de Proceso. Popayán: IEEE - 2016 IEEE 11th Colombian Computing Conference (CCC).

Agredo Delgado, V., Collazos, C., Fardoun, H., & Safa, N. (2017). Through Monitoring and Evaluation Mechanisms of the Collaborative Learning Process. En G. Meiselwitz (Ed.), *Social Computing and Social Media. Applications and Analytics* (págs. 20-31). Vancouver: Springer.

Agredo, V., Ruiz, P., Collazos, C., & Fardoun, H. (2017). Software tool to support the improvement of the collaborative learning process. *Colombian Conference on Computing .*

Agredo-Delgado, V., & Collazos, C. (2018). Framework for increasing collaboration and achieving group cognition. En J. Jurado, C. Collazos, & L. Muñoz, *Ingeniería colaborativa aplicaciones y usos desde la perspectiva de la Interacción Humano Computador* (págs. 419 - 424). Cali: Bonaventuriana.

Agredo-Delgado, V., Collazos, C., & Paderewski, P. (2016). Aplicación del procedimiento formal definido para evaluar, monitorear y mejorar el proceso de aprendizaje colaborativo en su etapa de Proceso mediante la creación de mecanismos. *I+ T+ C-Investigación, Tecnología y Ciencia*, 57-68.

Agredo-Delgado, V., Collazos, C., & Paderewski, P. (2016). Definición de mecanismos para monitorear, evaluar y mejorar el proceso de aprendizaje colaborativo. *Revista Colombiana De Computación*, 73-97.

Agredo-Delgado, V., Collazos, C., & Paderewski, P. (2016). Descripción formal de mecanismos para evaluar, monitorear y mejorar el proceso de aprendizaje colaborativo en su etapa de Proceso. *11 Congreso Colombiano de Computación* (págs. 1-8). IEEE.

Agredo-Delgado, V., Collazos, C., & Paderewski, P. (2016). Estudio de caso sobre mecanismos para evaluar, monitorear y mejorar el proceso de aprendizaje colaborativo. *Campus Virtuales*, 100-115.

Agredo-Delgado, V., Collazos, C., Fardoun, H., & Safa, N. (2017). Collaboration increase through monitoring and evaluation mechanisms of the collaborative learning process. *International Conference on Social Computing and Social Media* (págs. 20-31). Springer.

Agredo-Delgado, V., Ruiz, P., Collazos , C., & Fardoun, H. (2019). A reformation proposal of the Process phase in the computer-supported collaborative learning. En *Human-Computer Interaction* (págs. 17-29). Springer.

Agredo-Delgado, V., Ruiz, P., Collazos, C., & Fardoun, H. (2019). Refining the Process phase in the computer supported collaborative learning. En *Research and development in Learning Environments* (págs. 59-73). Puebla: Benemérita Universidad Autónoma de Puebla.

Agredo-Delgado, V., Ruiz, P., Collazos, C., & Mon, A. (2020). Building shared understanding with THUNDERS.

Agredo-Delgado, V., Ruiz, P., Collazos, C., & Moreira, F. (2019). *An exploratory study on the validation of THUNDERS: a process to achieve shared understanding in problem-solving activities.*

Agredo-Delgado, V., Ruiz, P., Collazos, C., Alghazzawi, D., & Fardoun, H. (2018). Towards a Framework Definition to Increase Collaboration and Achieve Group Cognition. *International Conference on Learning and Collaboration Technologies* (págs. 337-349). Springer.

Agredo-Delgado, V., Ruiz, P., Collazos, C., Fardoun, H., & Noaman, A. (2017). Software tool to support the improvement of the collaborative learning process. *12 Congreso Colombiano de Computación* (págs. 442-454). Springer.

Agredo-Delgado, V., Ruiz, P., Collazos, C., Moreira, F., & Fardoun, H. (2019). Methodological guidelines catalog to support the collaborative learning process. *Education in the Knowledge Society*.

Agredo-Delgado, V., Ruiz, P., Garzón, L., España, J., & Collazos, C. (2021). A strategy for building shared understanding in requirements engineering activities.

Agredo-Delgado, V., Ruiz, P., Mon, A., Collazos, C., & Fardoun, H. (2020). Towards a process definition for the shared understanding construction in Computer-Supported Collaborative Work. En V. Agredo-Delgado, P. Ruiz, & K. Villalba-Condori, *Human-Computer Interaction* (págs. 263-274). Springer.

Agredo-Delgado, V., Ruiz, P., Mon, A., Collazos, C., Moreira, F., & Fardoun, H. (2020). Validating the shared understanding construction in computer-supported collaborative work in a problem-solving activity. *World Conference on Information Systems and Technologies* (pp. 203-214). Springer.

Agredo-Delgado, V., Ruiz, P., Mon, A., Collazos, C., Moreira, F., & Fardoun, H. (2021). Applying a process for the shared understanding construction in computer-supported collaborative work: an experiment. *Computational and Mathematical Organization Theory*, 1-24.

Aken, J. (2004). Management research based on the paradigm of the design sciences: the quest for field-tested and grounded technological rules. *Journal of management studies*, 219-246.

Akkerman, S., Van den Bossche, P., Admiraal, W., Gijselaers, W., Segers, M., Simons, R.-J., & Kirschner, P. (2007). Reconsidering group cognition: From conceptual confusion to a boundary area between cognitive and socio-cultural perspectives? *Educational Research Review, 2*(1), 39-63.

Alam, A., Ullah, S., Rabbi, I., Khalid, S., & Din, F. (2013). Computer Supported Collaborative Work (CSCW) and Network Issues: A Survey. *International journal on information, 16*(11), 7995-8020.

Andrews-Todd, J., & Forsyth, C. (2020). Exploring social and cognitive dimensions of collaborative problem solving in an open online simulation-based task. *Computers in Human Behavior*.

Anindi, D., Rochintaniawati, D., & Rafikah Agustin, R. (2017). Interactive animation construction to measure students' collaborative problem solving. *AIP Conference Proceedings* (págs. 0600181-0600184). AIP Publishing LLC.

Arikoglu, E. (2011). *Impact des approches «scénario» et «persona» sur l'élicitation des exigences: une étude expérimentale.* Institut national polytechnique de Grenoble, Universite De Grenoble.

Arikoglu, E., Blanco, E., Pourroy, F., & Hicks, B. (2010). An empirical study to measure the effectiveness of scenarios to aid shared understanding of functional requirements. *DS 60: Proceedings of DESIGN 2010, the 11th International Design Conferenc* (págs. 619-628). Dubrovnik: Desing methods.

Armbrust, O., Ebel, J., Hammerschal, U., Münch, J., & Thoma, D. (2008). Experiences and Results from Tailoring and Deploying a Large Process Standard in a Company. *Software Process: Improvement and Practice SPIP*, 301-309.

Armbrust, O., Katahira, , M., Yuko , M., Munch, J., Nakao, H., & Ocampo, A. (2009). Scoping Software Process Lines. *Journal Software Process: Improvement and Practice - Examining Process Design and Change*, 181-197.

Armbrust, O., Katahira, M., Yuko, M., Jürgen, M., Haruka, N., & Ocampo, A. (2008). Scoping Software Process Models - Initial Concepts and Experience from Defining Space Standards. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 395-406.

Aubé, C., Rousseau, V., Brunelle, E., & Marques, D. (2018). The relevance of being "on the same page" to succeed as a project team: A moderated mediation model. *Motivation and Emotion*, 804–815.

Badke-Schaub, P., Lauche, K., & Neumann, A. (2007). Task–Team–Process: Assessment and Analysis of the Development of Shared Representations in an Engineering Team. *DTRS 7 Design Meeting Protocols Workshop Proceedings*, (págs. 97-109). London.

Bannon, L., Ehn, P., Greif, I., Howard, R., Kling, R., & Stefik, M. (1988). CSCW—what does it mean? (Panel Session). *CSCW '88 Proceedings of the 1988 ACM conference on Computer-supported cooperative work, 88*, 191-192.

Barker Scott, B. (2017). Creating a Collaborative Workplace: Amplifying Teamwork in Your Organization. *Queen's University IRC* , 1-9.

Barreto, A. S., Murta, L., & Cavalcanti da Rocha, A. R. (2011). Software Process Definition : a Reuse-based Approach. *Journal of the Universal Computer Science*, 1765-1799.

Barron, B. (2000). Achieving Coordination in Collaborative Problem-Solving Groups. *Journal of the Learning Sciences , 9*(4), 403-436 .

Barron, B. (2003). When smart groups fail. *The journal of the learning sciences, 12*(3), 307-359.

Baskerville, R., & Stage, J. (2001). Accommodating emergent work practices: Ethnographic choice of method fragments. *Realigning research and practice in information systems development*, 11-28.

Bates, K., Bird , G., Shea , J., Apkon, M., Shaddy, R., & Metlay, J. (2014). A tool to measure shared clinical understanding following handoffs to help evaluate handoff quality. *Journal of hospital medicine, 9*(3), 142-147.

Bedwell, W., Wildman, J., Diaz Granados, D., Salazar, M., Kramer, W., & Salas, E. (2012). Collaboration at work: An integrative multilevel conceptualization. *Human resource management review*, 128-145. doi:https://doi.org/10.1016/j.hrmr.2011.11.007

Beecroft, D., Duffy, G., & Moran, J. (2003). *The Executive Guide To Improvement And Change.* ASQ Quality Press.

Benet-Martínez, V., & Oliver, J. (1998). Los Cinco Grandes across cultures and ethnic groups: Multitrait-multimethod analyses of the Big Five in Spanish and English. *Journal of personality and social psychology*, 729.

Berggren, P., & Johansson, B. (2010). Developing an instrument for measuring shared. *Proceedings of the 7th International ISCRAM Conference.* Seattle: ISCRAM.

Berggren, P., Johansson, B., & Baroutsi, N. (2017). Assessing the quality of Shared Priorities in teams using content analysis in a microworld experiment. *Theoretical Issues in Ergonomics Science*.

Berggren, P., Johansson, B., Allard, O., & Torensjö, E. (2016). Training resilient medical teams. *Proceedings of the European Conference on Cognitive Ergonomics* (págs. 1-6). Nottingham: ACM.

Bertelsen, S. (2003). Construction as a complex system. *Proceedings for the 11th annual conference of the International Group for Lean Construction*, (págs. 11-23). Blacksburg.

Bittner, E., & Leimeister, J. (2014). Creating shared understanding in heterogeneous work groups: Why it matters and how to achieve it. *Journal of management information systems, 31*(1), 111-144.

Bjørnson, F., & Dingsøyr, T. (2008). Knowledge management in software engineering: A systematic review of studied concepts, findings and research methods used. *Information and Software Technology*, 1055-1068.

Bondarl, K., Katzy, B., & Mason, R. (2012). Shared understanding in networked organizations. *18th International ICE Conference on Engineering, Technology and Innovation* (págs. 1-11). IEEE.

Bottecchia , S., Cieutat, J.-M., & Jessel, J.-P. (2010). T.A.C: augmented reality system for collaborative tele-assistance in the field of maintenance through internet. *AH '10 Proceedings of the 1st Augmented Human International Conference*, 14.

Bowers, C., Pharmer, J., & Salas, E. (2000). When member homogeneity is needed in work teams: A meta-analysis. *Small group research, 31*(3), 305-327.

Bowers, J., & Benford, S. (1990). *Studies in computer supported cooperative work: theory, practice and design.* Amsterdam, The Netherlands: North-Holland Publishing Co.

Braunschweig, B., & Seaman, C. (2014). Measuring shared understanding in software project teams using pathfinder networks. *ESEM '14: Proceedings of the 8th ACM/IEEE International Symposium on Empirical Software Engineering and Measurement* (págs. 1-10). ACM.

Briggs , R., Kolfschoten, G., de Vreede, G.-J., & Douglas , D. (2006). Defining key concepts for collaboration engineering. *AMCIS 2006 Proceedings* (págs. 121–128). ACM.

Bronstein, L. (2003). A model for interdisciplinary collaboration. *Social work , 48*(3), 297-306.

Bunge, M. (2002). Philosophy of Science. *México: From Problem to Theory. New Brunswick, Transaction. Siglo Veintiuno Editores*.

Caballé, S., Daradoumis, T., Xhafa, F., & Juan, A. (2011). Providing effective feedback, monitoring and evaluation to on-line collaborative learning discussions. *Computers in Human Behavior*, 1372-1381.

Camacho, M., Hurtado-Alegria, J., & Ruiz-Melenje, P. (2016). Un método incremental para el análisis visual de modelos de proceso software. *Revista GTI*, 79-91.

Cannon-Bowers, J., Salas, E., & Converse, S. (1993). Shared mental models in expert team decision making. En J. N. (Ed.), *Individual and group decision making: Current Issues* (págs. 221-246). Hillsdale: Lawrence Erlbaum.

Cañadas Santiago, M., Durán Ceacero, F., Gallardo Jiménez, S., Martínez-Santaolalla Martínez, M., Peñas Troyano, M., Villarraga Rico, M., & Villegas Castellanos, J. (2002). Materiales didácticos en la resolución de problemas. *Investigación en el aula de Matemáticas, resolución de problemas.* Granada.

Care, E., Scoular, C., & Griffin, P. (2016). Assessment of collaborative problem solving in education environments. *Applied Measurement in Education, 29*(4), 250-264.

Carley, K. (1997). Extracting team mental models through textual analysis. *ournal of Organizational Behavior: The International Journal of Industrial, Occupational and Organizational Psychology and Behavior, 18*(S1), 533-558.

Carstensen, P., & Schmidt, K. (1999). Computer supported cooperative work: New challenges to systems design. En K. Itoh (Ed.), *Handbook of Human Factors* (págs. 619-636). CiteSeer.

Cash, P., Dekoninck, E., & Ahmed-Kristensen, S. (2017). Supporting the development of shared understanding in distributed design teams. *Journal of Engineering Design*, 147-170.

Centro InterUniversitario de desarrollo CINDA. (2000). *Las nuevas demandas del desempeño profesional y sus implicaciones para la docencia Universitaria.* Santiago de Chile: Colección gestión Universitaria.

Chen, J., Linh Nguyen, T., & Hac, Q.-A. (2021). The impacts of shared understanding and shared knowledge quality on emerging technology startup team's performance. *Knowledge Management Research & Practice*, 1-19.

Child, S., & Shaw, S. (2016). Collaboration in the 21st century: Implications for assessment. *Research Matters: A Cambridge Assessment publication*, 17-22.

Christiane Bittner, E., & Leimeister, J. (2013). Why Shared Understanding Matters--Engineering a Collaboration Process for Shared Understanding to Improve Collaboration Effectiveness in Heterogeneous Teams. *System Sciences (HICSS), 46th Hawaii International Conference*, 106-114.

Claes, W., Runeson, P., Hst, M., Ohlsson, M., Regnell, B., & Wessln, A. (2012). *Experimentation in Software Engineering.* Springer.

Clark, H., & Brennan, S. (1991). Grounding in Communication. En L. Resnick, J. Levine, & S. Teasley (Edits.), *Perspectives on Socially Shared Cognition* (págs. 127-149). Washington, DC: American Psychological Association.

Cohen, E., & Lotan, R. (2014). *Designing groupwork: strategies for the heterogeneous classroom.* Teachers College Press.

Collazos, C. (2014). Diseño de actividades de aprendizaje colaborativo asistidas por computador. *Revista Educación en ingeniería Universidad Militar Nueva Granada*, 143-149.

Collazos, C. (2014). Diseño de actividades de aprendizaje colaborativo asistido por computador. *Revista educación en ingeniería, 9*(17), 143-149.

Collazos, C., Guerrero, L., & Pino, J. (2004). computacional design principles to support the monitoring of collaborative learning process. *Journal of Advanced Technology for Learning, 1*(3), 174-180.

Collazos, C., Muñoz Arteaga, J., & Hernández, Y. (2014). *Aprendizaje colaborativo apoyado por computador.* LATIn Project.

Coughlan, J., & Macredie, R. (2002). Effective communication in requirements elicitation: a comparison of methodologies. *Requirements Engineering*, 47-60.

Cukurova, M., Luckin, R., Millán, E., & Mavrikis, M. (2018). The NISPI framework: Analysing collaborative problem-solving from students' physical interactions. *Computers & Education*, 93-109.

Darch, P., Carusi, A., & Jirotka, M. (2009). Shared understanding of end-users' requirements in e-Science projects. *E-Science Workshops, 5th IEEE International Conference*, 125-128.

De Haan, M. (2001). Intersubjectivity in models of learning and teaching: Reflections from a study of teaching and learning in a Mexican Mazahua community. En C. S. (Ed.), *The theory and practice of cultural-historical* (págs. 174-199). Aarhus: Aarhus University Press.

de Vreede, G.-J., Briggs, R., & Massey, A. (2009). Collaboration engineering: foundations and opportunities: editorial to the special issue on the journal of the association of information systems. *Journal of the Association for Information Systems, 10*(3), 7.
DeChurch, L., & Mesmer-Magnus, J. (2010). Measuring shared team mental models: A meta-analysis. *Group dynamics: Theory, research, and practice*, 1-14.
DeFranco, J., Neill, C., & Clariana, R. (2011). A cognitive collaborative model to improve performance in engineering teams—A study of team outcomes and mental model sharing. *Systems Engineering, 14*(3), 267-278.
Deshpande, N., de Vries, B., & van Leeuwen, J. (2005). Building and supporting shared understanding in collaborative problem-solving. *Information Visualisation IEEE, Proceedings. Ninth International Conference* , 737-742.
Di Eugenio, B., Jordan, P., Thomason, R., & Moore, J. (2000). The agreement process: An empirical investigation of human–human computer-mediated collaborative dialogs. *International Journal of Human-Computer Studies*, 1017-1076.
Dillenbourg , P., Baker, M., Blaye , A., & O'Malley , C. (1996). The evolution of research on collaborative learning. *Learning in humans and machine: Towards an interdisciplinary learning science*, 189-211.
Dillenbourg, P. (1999). *Collaborative learning: Cognitive and computational approaches. advances in learning and instruction series.* New York: Elsevier Science.
Dossick, C., Osburn, L., & Asl, B. A. (2017). Measuring Shared Understanding: Developing Research Methods for Empirical Research on Interdisciplinary Engineering Team Practices. *15th Engineering Project Organization Conference*.
Du, J., Jing , S., & Liu, J. (2010). Shared design thinking process model for supporting collaborative design. *In Computer Supported Cooperative Work in Design (CSCWD) IEEE, 14th International Conference*, 65-70.
Durán, E., Calo, M., & Argañaraz, G. (2012). Los roles en grupos de aprendizaje colaborativos soportado por computadora: un método de detección automática. *XVIII Congreso Argentino de Ciencias de la Computación.* Universidad Nacional de la Plata.
Echeverria, V., Martinez-Maldonado, R., & Buckingham Shum, S. (2019). Towards collaboration translucence: Giving meaning to multimodal group data. *Proceedings of the 2019 chi conference on human factors in computing systems*, (págs. 1-16).
Edelson, R. (2000). *The influence of supervisor-subordinate mental model congruence on group effectiveness and subordinates' satisfaction with their supervisor.* Degree: Ph.D.
Ellis, C., & Wainer, J. (1999). Groupware and Computer Supported Cooperative Work. En *Multiagent Systems: a modern approach to distributed artificial intelligence* (págs. 425-458).
Ensley, M., & Pearce, C. (2001). Shared cognition in top management teams: Implications for new venture performance. *ournal of Organizational Behavior: The International Journal of Industrial, Occupational and Organizational Psychology and Behavior, 22*(2), 145-160.
Ernst, K., McComb, S., & Ley, C. (2018). Nurse-to-nurse shift handoffs on medical–surgical units: A process within the flow of nursing care. *Journal of Clinical Nursing*, e1189-e1201.
Eseryel, D., Ganesan, R., & Edmonds, G. (2002). Review of Computer-Supported Collaborative Work Systems. *Educational Technology & Society, 5*(2), 130-136.
Evermann, J., Haggard, G., & Ferreira, J. (2007). Improving mutual understanding of development artifacts: A semiotics-based approach. *13th Americas Conference on Information Systems AMCIS 2007 Proceedings*, (págs. 459-471).
Feiler, P. H., & Humphrey, W. S. (1993). Software process development and enactment: concepts and definitions. *Proceedings of the Second International Conference on the Software Process-Continuous Software Process Improvement*, 28-40.
Feldman, M., & Rafaeli, A. (2002). Organizational routines as sources of connections and understandings. *Journal of Management Studies*, 309-331.
Fischer, G. (2000). Symmetry of ignorance, social creativity, and meta-design. *Knowledge-Based Systems, 13*(7), 527-537.
Frankel, N., & Gage, A. (2009). *Fundamentos de monitoreo y evaluación.* Agency for International Development (USAID).

Garcia, A., Molina, J., Martınez, D., & Gonzalez, P. (2008). Enhancing collaborative manipulation through the use of feedback and awareness in CVEs. *Proceedings of the 7th ACM SIGGRAPH international Conference on Virtual-Reality Continuum and Its Applications in industry*.

Garfield, M., & Alan R. , D. (2012). Toward an integrated model of group development: Disruption of routines by technology-induced change. *Journal of Management Information Systems, 29*(3), 43-86.

Gašević, D., Joksimović, S., Eagan, B., & Shaffer, D. (2019). SENS: Network analytics to combine social and cognitive perspectives of collaborative learning. *Computers in Human Behavior*, 562-577.

Ginsberg, M., & Quinn, L. (1995). *Process tailoring and the the software capability maturity model.* Pittsburgh: Software Engineering Institute.

Gomes, D., & Tzortzopoulos, P. (2018). Building shared understanding during early design. *26th Annual Conference of the International Group of Lean Construction*, (págs. 473–483).

Gomes, D., Tzortzopoulos, P., & Kagioglou, M. (2016). Collaboration through shared understanding in early design stage. *24th Ann. Conf. of the Int'l. Group for Lean Construction*, (págs. 63-72). Boston.

Graesser, A., Foltz, P., Rosen, Y., Shaffer, D., Forsyth, C., & Germany, M.-L. (2018). Challenges of Assessing Collaborative Problem Solving. In E. Care, P. Griffin, & M. Wilson (Eds.), *Assessment and Teaching of 21st Century Skills* (pp. 75-91). Springer.

Graf, S., & Bekele, R. (2006). Forming heterogeneous groups for intelligent collaborative learning systems with ant colony optimization. Berlin: International conference on intelligent tutoring systems, Springer.

Granados, R. (2000). Constructing intersubjectivity in representational design activities. *The Journal of Mathematical Behavior, 19*(4), 503-530.

Groeben, N., & Scheele, B. (2000). Dialogue-hermeneutic method and the" research program subjective theories. *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research.*

Grøtan, T., Albrechtsen, E., & Skarholt, K. (2009). How shared situational awareness influence organizational accident risk in the offshore oil industry. *Proceeding of ESREL 2009 conference* (págs. 2207–2214). Prague: CRC Press.

Grudin, J. (1988). Why CSCW applications fail: problems in the design and evaluationof organizational interfaces. *Proceedings of the 1988 ACM conference on Computer-supported cooperative work*, 85-93.

Grudin, J. (1994). Computer-supported cooperative work: History and focus. *Computer, 27*(5), 19-26.

Gulgun, A. (2017). Achievement of joint perception in a computer supported collaborative learning environment: A case study. *Turkish Online Journal of Distance Education*, 78-90.

Haavik, T. (2011). Chasing shared understanding in drilling operations. *Cognition, Technology & Work*, 281-294.

Häkkinen, P., Järvelä, S., Mäkitalo-Siegl, K., Ahonen, A., Näykki, P., & Valtonen, T. (2017). Preparing teacher-students for twenty-first-century learning practices (PREP 21): a framework for enhancing collaborative problem-solving and strategic learning skills. *Teachers and Teaching: theory and practice, 23*, 25-41.

Hansen, B. (2018). *Top 15 Problem Solving Activities for Your Team to Master*. Recuperado el 29 de Diciembre de 2018, de https://www.wrike.com/blog/top-15-problem-solving-activities-team-master/

Harmsen, A., Brinkkemper, J., & Oei, J. (1994). *Situational method engineering for information system project approaches.* University of Twente: Department of Computer Science.

Haumer, P. (2007). *Eclipse process framework composer.* Eclipse Foundation.

Henderson-Seller, B. (2010). Situational Method Engineering: Stateof art of the-Art Review. *Journal of the Universal Computer Science, 16*(3), 424–478.

Henderson-Seller, B., Ralyté, J., & Ågerfalk, P. (2014). Situational method engineering. *Situational Method Engineering, Springer, 2014, ch. Method Chu*, 1–310.

Henninger , S. (2001). Turning development standards into repositories of experiences. *Software Process: Improvement and Practice*, 141-155.

Hermans, L., Haasnoot, M., Maat, J., & Kwakkel, J. (2017). Designing monitoring arrangements for collaborative learning about adaptation pathways. *Environmental Science & Policy*, 29-38.

Hernandez Sampieri, R., Paulina Mendoza, C., & Méndez Valencia, S. (2018). *Metodología de La Investigación*. McGraw-Hill Interamericana.

Hevner, A., March, S., Park, J., & Ram, S. (2004). Design science research in information systems. *MIS quarterly*, 75-105.

Hey, J., Joyce , C., & Beckman, S. (2007). Framing innovation: negotiating shared frames during early design phases. *Journal of Design Research*, 79-99.

Hill, A., Song, S., Dong, A., & Agogino, A. (2001). Identifying shared understanding in design using document analysis. *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* (págs. 309-315). American Society of Mechanical Engineers.

Hinds, P., & Weisband, S. (2003). Knowledge sharing and shared understanding in virtual teams. En C. Gibson, & S. Cohen (Edits.), *In Virtual teams that work: Creating conditions for virtual teams effectiveness* (págs. 21-36.). San Francisco: Jossey-Bass.

Hoegl, M., & Gemuenden, H. (2001). Teamwork quality and the success of innovative projects: A theoretical concept and empirical evidence. *Organization science, 12*(4), 435-449.

Hollenbach, C., & Frakes, W. (1996). Software Proeess Reuse in an Industrial Setting. *Proceedings of Fourth IEEE International Conference on Software Reuse. Orlando, FL, USA*.

Hossein, S., & Natsu, C. (1997). Characterizing a Software Process Maturity Model for Small Organizations. *ACM SIGICE Bulletin, 23*, 2-11.

Hsieh, Y. (2006). Culture and Shared Understanding in Distributed Requirements Engineering. *IEEE International Conference on Global Software Engineering (ICGSE'06)* (págs. 101-108). IEEE.

Hughes, J., Randall, D., & Shapiro, D. (1991). CSCW: Discipline or Paradigm? *Proceedings of the Second European Conference on Computer-Supported Cooperative Work ECSCW'91*, 309-323.

Humayun, M., & Gang, C. (2013). An empirical study on improving shared understanding of requirements in GSD. *International Journal of Software Engineering and its Applications*, 113-134. doi:10.1002/piq.20034

Humphrey, W. (1989). The software engineering process: definition and scope. *ACM SIGSOFT Software Engineering Notes , 14*(4), 82-83.

Humphrey, W. S. (1989). Managing the Software Process. *Addison-Wesley Longman*.

Hunt, W. (2000). *Shared Understanding: Implications for Computer Supported Cooperative Work*. Recuperado el 1 de Diciembre de 2018, de http://www.dgp.utoronto.ca/people/WilliamHunt/qualifier.html

Hurtado , J., Lagos, A., Bergel, A., & Bastarrica, M. (2010). Software process model blueprints. *Conference on new modeling concepts for today's software processes*.

Hurtado Alegría, J., Bastarrica, M., & Bergel, A. (2011). Analyzing software process models with AVISPA. *Proceedings of the 2011 International Conference on Software and Systems Process* (págs. 23-32). ACM.

Hurtado, C., & Guerrero, L. (2006). *ColaboQuim: Una aplicación para apoyar el aprendizaje colaborativo en química.* Santiago de Chile: Universidad de Chile.

Hurtado, J. A., & Bastarrica, M. C. (2012). Building Software Process Lines with CASPER. *International Conference on Software and Systems Processes. ICSSP*.

Hurtado, J., Bastarrica , M., & Bergel, A. (2013). AVISPA: A Tool for Analyzing Software Process Models. *Journal of software: Evolution and Process*.

Hurtado, J., Bastarrica, M., & Bergel, A. (2013). AVISPA: A Tool for Analyzing Software Process Models. *Journal of software: Evolution and Process, 26*(4), 434-450.

Ilgen, D., Hollenbeck, J., Johnson, M., & Jundt, D. (2005). Teams in organizations: From input-process-output models to IMOI models. *Annu. Rev. Psychol, 56*, 517-543.

Ingrid, M., Swaak, J., & Kessels, J. (2002). Assessing group learning and shared understanding in technology-mediated interaction. *Educational Technology & Society, 5*, 35-47.

Izquierdo Alonso, M., & Iborra Cuellar, A. (2010). ¿ Cómo afrontar la evaluación del aprendizaje colaborativo? Una propuesta valorando el proceso, el contenido y el producto de la actividad grupal. *Revista general de información y documentación*, 221-241.

Jacobson, I., Booch, G., & Rumbaugh, J. (1999). Unified Software Development Process.

Jentsch, C., Beimborn, D., Jungnickl, C., & Renner, G. (2014). How to measure shared understanding among business and IT. *Academy of Management Conference 2014* (pág. 16980). New York: Academy of Management.
Ji, G., & Bilmes, J. (2005). Dialog act tagging using graphical models. *Proceedings.(ICASSP'05). IEEE International Conference on Acoustics* (págs. 1-33). IEEE.
Johnson , D., & Johnson, R. (1990). *Circles of Learning: Co-Operation in the Classroom.* Interaction Book Company.
Johnson, D., Johnson, R., & Smith, K. (2013). Cooperative Learning: Improving University instruction by basing practice on validated theory. *Journal on Excellence in University Teaching, 25*(4), 1-26.
Johnson, R., & Johnson, D. (2008). Active learning: Cooperation in the classroom. *The annual report of educational psychology in Japan, 47*, 29.
Johnson, T., & O'Connor, D. (2008). Measuring team shared understanding using the analysis-constructed shared mental model methodology. *Performance Improvement Quarterly*, 113-134.
Kaendler, C., Wiedmann, M., Leuders, T., Rummel, N., & Spada, H. (2016). Monitoring Student Interaction during Collaborative Learning: Design and Evaluation of a Training Program for Pre-Service Teachers. *SAGE Journals, 15*(1), 44-64.
Karlsson, F., & Wistrand, K. (2006). Combining method engineering with activity theory: theoretical grounding of the method component concept. *European Journal of Information Systems*, 82–90.
Kasse, J., Xu, L., deVrieze, P., & Bai, Y. (2018). The need for compliance verification in collaborative business processes. *Working Conference on Virtual Enterprises* (págs. 217-229). Springer.
Kaufer, D., & Carley , K. (1993). *Communication at a Distance.* Hillsdale: LaWrence Erlbaurn.
Kauffmann, D., & Carmi, G. (2020). E-Collaboration in Virtual Teams: Trust as a Facilitator of Development. *Knowledge Management, Innovation, and Entrepreneurship in a Changing World*, 210-242.
Kendall, M. (1975). *Rank Correlation Methods.* London: Charles Griffin & Company Ltd.
Kim, J., & Shah, J. (2016). Improving team's consistency of understanding in meetings. *IEEE Transactions on Human-Machine Systems* , 625-637.
Kip, K., & Schaefer, A. (2014). *Creating a collaborative organizational culture.* Kenan-Flager Business School.
Kitchenham, B., & Charters, S. (2007). Guidelines for performing Systematic. *Engineering*, 1051.
Kleinsmann, M., & Valkenburg, R. (2008). Barriers and enablers for creating shared understanding in co-design projects. *Design studies, 29*(4), 369-386.
Kleinsmann, M., Bujis, J., & Valkenburg, R. (2010). Understanding the complexity of knowledge integration in collaborative new product development teams: A case study. *Journal of Engineering and Technology Management, 27*(1-2), 20-32.
Kleinsmann, M., Valkenburg, R., & Buijs, J. (2007). Why do (n't) actors in collaborative design understand each other? An empirical study towards a better understanding of collaborative design. *CoDesign*, 59-73.
Klimoski, R., & Mohammed, S. (1994). Team mental model: Construct or metaphor? *Journal of management, 20*(2), 403-437.
Kling, R. (1991). Cooperation, coordination and control in computer-supported work. *Communications of the ACM, 34*(12), 83-88.
Kniel, J., & Comi, A. (2021). Riding the same wavelength: Designers' perceptions of shared understanding in remote teams. *Sage Journal*, 1-14.
Kolfschote, G., & de Vreede, G.-J. (2007). The collaboration engineering approach for designing collaboration processes. *International Conference on Collaboration and Technology* (págs. 95-110). Berlin: Springer.
Kozar, O. (2010). Towards Better Group Work: Seeing the Difference between Cooperation and Collaboration. *English Teaching Forum , 48*(2), 16-23.
Lai, E. (2011). *Collaboration: A Literature Review.* Pearson.

Langan-Fox, J., Anglim, J., & Wilson, J. (2004). Mental models, team mental models, and performance: Process, development, and future directions. *Human Factors and Ergonomics in Manufacturing & Service Industries, 14*(4), 331-352.

Langan-Fox, J., Wirth, A., Code, S., Langfield-Smith, K., & Wirth, A. (2001). Analyzing shared and team mental models. *International journal of industrial ergonomics, 28*(2), 99-112.

Lauriac, N. (2016). Diseño e implementación de un sistema de monitoreo. *Terre des hommes*.

Leeann, K. (2015). *A practical guide to collaborative working.* CollaborationNI NICVA.

Lescano, G., & Costaguta, R. (2018). COLLAB: Conflicts and Sentiments in chats. *Proceedings of the XIX International Conference on Human Computer Interaction* (págs. 1-4). New York: ACM.

Lescano, G., Costaguta, R., & Amandi, A. (2016). Genetic algorithm for automatic group formation considering student's learning styles. *8th Euro American Conference on Telematics and Information Systems (EATIS)* (págs. 1-8). Cartagena: IEEE.

Levesque, L., Wilson, J., & Wholey, D. (2001). Cognitive divergence and shared mental models in software development project teams. *Journal of Organizational Behavior: The International Journal of Industrial, Occupational and Organizational Psychology and Behavior, 22*(2), 135-144.

Lind, M., & Zmud, R. (1991). The influence of a convergence in understanding between technology providers and users on information technology innovativeness. *Organization science* , 195-217.

Londoño, G. (2008). Aprendizaje colaborativo presencial, aprendizaje colaborativo mediado por computador e interacción: Aclaraciones, aportes y evidencias. *Educación, comunicación y tecnología, 2*(4).

López Trujillo, Y., & André Ampuero, M. (2006). Roles en el proceso de desarrollode software para las empresas cubanas. *Industrial*, 31-35.

Lotan, R., Swanson, P., & LeTendre, G. (1992). Strategies for detracked middle schools: Curricular materials, instructional strategies, and access to learning. *Middle School Journal, 24*(1), 4-14.

Lowry, P., & Nunamaker, J. (2003). Using Internet-based, distributed collaborative writing tools to improve coordination and group awareness in writing teams. *EEE Transactions on Professional Communication, 46*(4), 277-297.

Lowry, P., Albrech, C., Lee, J., & Nunamaker, J. (2002). Users' experiences in collaborative writing using Collaboratus, an Internet-based collaborative work. *System Sciences, 2002. HICSS. Proceedings of the 35th Annual Hawaii International Conference*, 243-252.

Lu, S. (2004). Beyond concurrent engineering: a new foundation for collaborative engineering, the worldwide engineering grid. *Proceedings of 11th International Conference on Concurrent Engineering*, (págs. 27-40). Beijing.

Lund, M., Collazos, C., & Ormeño, E. (2012). Modelo de apoyo para la preparación de actividades experimentales destinadas a la enseñanza de Ingeniería de Software en ambientes colaborativos y distribuidos geográficamente. *XVIII Congreso Argentino de Ciencias de la Computación.* La plata.

Lv, R.-j., Zhao, Z., Chen, X.-c., & He, L.-j. (2013). Shared knowledge and shared understanding between cio and top management team: a literature review. *The 19th International Conference on Industrial Engineering and Engineering Management* (págs. 759-766). Berlin: Springer.

MacMillan, J., Paley, M., Entin, E., & Entin, E. (2005). Questionnaires for Distributed Assessment. En N. Stanton, K. Hedge, E. Brookhuis, E. Salas, & H. Hendricks, *Handbook of Human Factors Methods* (págs. 51-59). London.

Margaret, T. (1994). Establishing mutual understanding in systems design: An empirical study. *Journal of Management Information Systems*, 159-182.

Marks, M., Burke, C., Sabella, M., & Zaccaro, S. (2002). The Impact of Cross-Training on Team Effectiveness. *Journal of Applied Psychology, 87*(1), 3-13.

Martin, G., & Fricker, S. (2015). On shared understanding in software engineering: an essay. *Computer Science-Research and Development, 30*(3), 363-376.

Martinie, C., Palanque, P., & Winckler, M. (2011). Structuring and composition mechanisms to address scalability issues in task models. *IFIP Conference on Human-Computer Interaction* (págs. 589-609). Berlin: Springer.

Mathieu, J., Heffner, T., Goodwin, G., Salas, E., & Cannon-Bowers, J. (2000). The influence of shared mental models on team process and performance. *Journal of applied psychology, 85*(2), 273.

Mayer, R., & Wittrock, M. (1996). Problem-solving transfer. En D. Berliner, & R. Calfee (Edits.), *Handbook of educational psychology* (págs. 47-62). New Jersey: Routledge.

McCarthy, S., O'Raghallaigh, P., Fitzgerald, C., & Adam, F. (2019). Towards a framework for shared understanding and shared commitment in agile distributed ISD project teams. *Proceedings of the 27th European Conference on Information Systems.* Sweden.

McComb, S., Henneman, E., Hinchey, K., Richardson, C., Peto, R., Kleppel, R., & Rose, D. (2012). Improving teamwork on general medical units: when teams do not work face-to-face. *Joint Commission Journal on Quality and Patient Safety*, 471-478.

McGuinness, B., & Foy, L. (2000). A subjective measure of SA: the Crew Awareness Rating Scale (CARS). *Proceedings of the first human performance, situation awareness, and automation conference*, (págs. 286-291). Savannah.

McKay, J. (1998). Using cognitive mapping to achieve shared understanding in information requirements determination. *Australian Computer Journal*, 139-145.

Mendoza García, J. (2021). Vygotsky y la construcción del conocimiento. *Revista Universidad Pedagogica Nacional* , 1-32.

Mohammed , S., & Dumville, B. (2001). Team mental models in a team knowledge framework: expanding theory and measurement across disciplinary boundaries. *Journal of Organizational Behavior: The International Journal of Industrial, Occupational and Organizational Psychology and Behavior, , 22*(2), 89-106.

Mohammed, S., & Ringseis, E. (2001). Cognitive diversity and consensus in group decision making: The role of inputs, processes, and outcomes. *Organizational behavior and human decision processes, 85*(2), 310-335.

Mohammed, S., Ferzandi, L., & Hamilton, K. (2010). Metaphor no more: A 15-year review of the team mental model construct. *Journal of Management, 36*(4), 876-910.

Moşteanu, N. R. (2021). eaching and learning techniques for the online environment. how to maintain students' attention and achieve learning outcomes in a virtual environment using new technology. *International Journal of Innovative Research and Scientific Studies*, 278-290.

Mulder, I. (1999). *Understanding technology mediated interaction processes. a theoretical context.* Telematica Instituut.

Mulder, I., & Swaak, J. (2000). *How do globally dispersed teams communicate? Results of a case study.* Enschede: Telematica Instituut.

Mulder, I., & Swaak, J. (2002). Assessing group learning and shared understanding in technology-mediated interaction. *Educational Technology & Society*, 35-47.

Munson, S., Kervin, K., & Robert Jr., L. (2014). Monitoring email to indicate project team performance and mutual attraction. *Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing* (págs. 542-549). ACM.

Nakakawa, A., Van Bommel, P., Proper , E., & Mulder, H. (2018). A Situational Method for Creating Shared Understanding on Requirements for an Enterprise Architecture. *International Journal of Cooperative Information Systems*.

Naseebah, M., Mohsen, A., & Bechkoum, K. (2019). Group formation techniques in computer-supported collaborative learning: A systematic literature review. *Technology, Knowledge and Learning*, 169-190.

Neave, H. (2002). *Elementary Statistics Tables.* London: Routledge.

Norman, D. (1991). Cognitive Artifact. En J. Carroll (Ed.), *Designing interaction* (págs. 17-38). Cambridge, UK: Cambridge University Press.

O'Donnell, A., & O'Kelly, J. (1994). Learning from peers: Beyond the rhetoric of positive results. *Educational Psychology Review, 6*(4), 321-349.

Olson, T., Reizer, N., & Over, J. (1994). A Software Process Framework for the SEI Capability Maturity Modelsm. *Software Engineer Institute September*.

OMG. (2007). Software & Systems Process Engineering Metamodel (SPEM). *OMG Std, 2*, 18-71.

O'Neil, H., Chuang, S.-h., & Chung, G. (2003). Issues in the computer-based assessment of collaborative problem solving. *Assessment in Education: Principles, Policy & Practice , 10*(3), 361-373.

Onrubia, J., & Engel, A. (2012). The role of teacher assistance on the effects of a macro-script in collaborative writing tasks. *International Journal of Computer-Supported Collaborative Learning, 7*(1), 161–186.

Oppl, S. (2017). Supporting the collaborative construction of a shared understanding about work with a guided conceptual modeling technique. *Group Decision and Negotiation*, 247-283.

Organization for economic co-operation and development (OECD). (2013). *PISA 2015 Collaborative Problem Solving Framework.*

Pascual, R. (1999). Tools for capturing and training shared understanding in teams. *International conference on people in control (Human interfaces in control rooms, cockpits and command centres*, 57 – 63.

Paulus, P., & Nijstad, B. (2003). *Group creativity: Innovation through collaboration.* Oxford University Press.

Peng, X., & Ramesh, B. (2007). Software Process Tailoring: An Empirical Investigation. *Journal of Management Information Systems*, 293-328.

Persico, D., Pozzi, F., & Sarti, L. (2009). Design patterns for monitoring and evaluating CSCL processes. *Computers in Human Behavior, 25*(5), 1020-1027.

Persico, D., Pozzi, F., & Sarti, L. (2010). Monitoring collaborative activities in computer supported collaborative learning. *Distance Education, 31*(1), 5-22.

Peterson, E., Mitchell, T., Thompson, L., & Renu, B. (2000). Collective efficacy and aspects of shared mental models as predictors of performance over time in work groups. *Group Processes & Intergroup Relations , 3*(3), 296-316.

Piirainen, K., Kolfschoten , G., & Lukosch, S. (2012). The joint struggle of complex engineering: A study of the challenges of collaborative design. *International Journal of Information Technology & Decision Making, 11*(6), 1087-1125.

Pino, F., Piattini, M., & Horta Travassos, G. (2013). Managing and developing distributed research projects in software engineering by means of action-research. *Revista Facultad de Ingeniería Universidad de Antioquia*, 61-74.

Pressman, R. (2010). *Ingeniería del Software: Un enfoque práctico.* Mc Grall Hill.

Preston, D., Karahanna, E., & Rowe, F. (2006). Development of shared understanding between the chief information officer and top management team in US and French organizations: A cross-cultural comparison. *IEEE Transactions on Engineering Management*, 191-206.

Quashigah, E. (2017). *Collaborative problem solving activities in natural learning situations: a process oriented case study of teacher education students.* Oulu: Master's Thesis in Education.

Ralyté, J. (2013). Situational Method Engineering in Practice: A Case Study in a Small Enterprise. *CAiSE Forum*, 17–24.

Rama, J., & Bishop , J. (2006). A survey and comparison of CSCW groupware applications. *Proceeding SAICSIT '06 Proceedings of the 2006 annual research conference of the South African institute of computer scientists and information technologists on IT research in developing countries*, 198-205.

Razmerita, L., & Brun, A. (2011). Collaborative learning in heterogeneous classes. Netherlands: he 3rd International Conference on Computer Supported Education.

Redlich, B., Siemon, D., Lattemann, C., & Robra-Bissantz, S. (2017). Shared Mental Models in Creative Virtual Teamwork. *Proceedings of the 50th Hawaii International Conference on System Sciences* (págs. 464-473). HYCSS.

Roache, P. (1998). *Verification and validation in computational science and engineering.* Albuquerque: NM: Hermosa.

Robillard, P., & Robillard, M. (2000). Types of collaborative work in software engineering. *Journal of Systems and Software*, 219-224.

Rodríguez del Pino, J., Rubio Royo, E., & Hernández Figueroa, Z. (2010). VPL: laboratorio virtual de programación para Moodle. XVI Jornadas de Enseñanza Universitaria de la Informática. Universidade de Santiago de Compostela. Escola Técnica Superior d'Enxeñaría.

Rogoff, B., & Wertsch, J. (1984). *Children's Learning in the `Zone of Proximal Development.* San Francisco, CA: Jossey-Bass Inc., Publishers.

Rojas Díaz, D., Zambrano Matamala, C., & Salcedo Lagos, P. (2020). Método para la formación de grupos colaborativos mediante disponibilidad léxica. *Revista electrónica de investigación educativa*.

Romero, D., & Molina, A. (2010). Virtual organisation breeding environments toolkit: reference model, management framework and instantiation methodology. *Production Planning and Control, 21*(2), 181-217.

Roschelle, J., & Teasley, S. (1995). The Construction of Shared Knowledge in Collaborative Problem Solving. En *Computer supported collaborative learning* (págs. 69-97). Berlin, Heidelberg: Springer.

Rosen, Y. (2015). Computer-based assessment of collaborative problem solving: Exploring the feasibility of human-to-agent approach. *International Journal of Artificial Intelligence in Education*, 380-406.

Rosen, Y., & Foltz, P. (2014). Assessing collaborative problem solving through automated technologies. *Research and Practice in Technology Enhanced Learning, 9*(3), 389-410.

Rosenkranz, C., Hummel, M., & Holten, R. (2016). The Role of Shared Understanding in Distributed Scrum Development: An Empirical Analysis. *Proceedings of the European Conference on Information Systems (ECIS)*.

Rosenman, E., Dixon, A., Webb, J., Brolliar, S., Golden, S., Jones, K., . . . Fernandez, R. (2018). A simulation-based approach to measuring team situational awareness in emergency medicine: A multicenter, observational study. *Academic Emergency Medicine, 25*(2), 196-204.

Rouse, W., & Morris, N. (1986). On looking into the black box: Prospects and limits in the search for mental models. *Psychological bulletin, 100*(3), 349.

Ruiz, F., & Verdugo , J. (2008). *Guía de Uso de SPEM 2 con EPF Composer.* Universidad de Castilla-La Mancha.

Rummel, N., & Spada, H. (2005). Learning to collaborate: An instructional approach to promoting collaborative problem solving in computer-mediated settings. *The Journal of the Learning Sciences, 14*(2), 201-241.

Runeson, P., & Höst, M. (2009). Guidelines for conducting and reporting case study research in software engineering. *(D. Sjoberg, Ed.) Empirical Software Engineering,* , 131-164.

Rupert, B., & Pehrson, S. (2019). *Group processes: Dynamics within and between groups.* John Wiley & Sons.

Saiz, J., Rodríguez, R., & Ortiz Bas, A. (2005). A performance measurement system for virtual and extended enterprises. En L. Camarinha-Matos, H. Afsarmanesh, & A. Ortiz (Edits.), *Working Conference on Virtual Enterprises* (págs. 285-292). Valencia: Springer.

Salas, E., Rosen, M., Burke, S., Nicholson, D., & Howse, W. (2007). Markers for enhancing team cognition in complex environments: The power of team performance diagnosis. *Aviation, space, and environmental medicine*, B77-B85.

Sandler, T. (1992). *Collective action: Theory and applications.* University of Michigan Press.

Sanyal, S., & Wamique Hisam, M. (2018). The impact of teamwork on work performance of employees: A study of faculty members in Dhofar University. *IOSR Journal of Business and Management*, 15-22.

Sarmiento, J., & Stahl, G. (2008). Extending the joint problem space: time and sequence as essential features of knowledge building. *InProceedings of the 8th international conference on International conference for the learning sciences* (págs. 295-302). International Society of the Learning Sciences.

Scagnoli, N. (2005). Estrategias para motivar el aprendizaje colaborativo en cursos a distancia. University of Illinois at Urbana-Champaign.

Scagnoli, N. (2005). Estrategias para motivar el aprendizaje colaborativo en cursos a distancia. University of Illinois at Urbana-Champaign.

Schmidt, K. (1994). *Modes and mechanisms of interaction in cooperative work.* Roskilde: Risø National Laboratory.

Schulte, S., Schuller, D., Steinmetz, R., & Abels, S. (2012). Plug-and-Play Virtual Factories. *IEEE Internet Computing, 16*(5), 78-82.

Sena Ferreira, P., Shamsuzzoha, A., Toscano , C., & Cunha, P. (2012). Framework for performance measurement and management in a collaborative business environment. *International Journal of Productivity and Performance Management, 61*(6), 672-690.

Shamsuzzoha, A., Helo, P., & Sandhu, M. (2017). Virtual enterprise collaborative processes monitoring through a project business approach. *International Journal of Computer Integrated Manufacturing, 30*(10), 1093-1111.

Sieck, W., Rasmussen, L., & Smart, P. (2010). Cultural network analysis: A cognitive approach to cultural modeling. *Network science for military coalition operations: Information exchange and interaction*, 237-255.

Siemens, G. (2014). *Connectivism: A learning theory for the digital age*. Recuperado el 25 de 1 de 2019, de http://er.dut.ac.za/handle/123456789/69

Slavin, R. (1987). Developmental and motivational perspectives on cooperative learning: A reconciliation. *Child development*, 1161-1167.

Slavin, R. (1990). *Cooperative learning: Theory, research, and practice.* Prentice-Hall.

Slavin, R. (1991). Synthesis of research of cooperative learning. *Educational leadership, 48*(5), 71-82.

Slavin, R. (1996). Research on cooperative learning and achievement: What we know, what we need to know. *Contemporary educational psychology, 21*(1), 43-69.

Smart, P. (2011). *Understanding and Shared Understanding in Military Coalitions.* Southampton: Web & Internet Science.

Smart, P., Mott, D., Sycara, K., Braines, D., Strub, M., & Shadbolt, N. (2009). Shared understanding within military coalitions: A definition and review of research challenges. United Kingdom: University of Southampton Institutional Repository.

Soares Correa da Silva, F., & Agusti-Cullell, J. (2008). Information Flow and Knowledge Sharing. En *Shared understanding* (págs. 103-118). Elsevier.

Sobernig, S. (2020). Tailor Made: Situational Method Engineering for Empirical SE Research. *Software Engineering 2020*, (págs. 155-162).

Solano, A., Granollers, T., & Collazos, C. (2015). Modelado de procesos colaborativos extendiendo elementos de la notación HAMSTERS. *Revista Colombiana de Computación*, 144-161.

Sommerville, I. (1996). Software process models. *ACM computing surveys (CSUR)*, 269-271.

Sommerville, I. (2011). *Software engineering 9th Edition.* Addison Wesley Publishing Company.

Souren, P., Fang, H., & Dennis, A. (2018). Group atmosphere, shared understanding, and team conflict in short duration virtual teams. *Negotiation, leadership, and technology*.

Stahl, G., Koschmann, T., & Suthers, D. (2006). Computer-supported collaborative learning: An historical perspective. *Cambridge handbook of the learning sciences,*.

Stein, D., Wanstreet, C., Glazer, H., Engle, C., Harris, R., Johnston, S., . . . Trinko, L. (2007). Creating shared understanding through chats in a community of inquiry. *The Internet and Higher Education*, 103-115.

Stewart, A., Vrzakova, H., Sun, C., Yonehiro, J., Stone, C., Duran, N., . . . D'Mello, S. (2019). I Say, You Say, We Say: Using Spoken Language to Model Socio-Cognitive Processes during Computer-Supported Collaborative Problem Solving. *Proceedings of the ACM on Human-Computer Interaction 3.CSCW (2019)* (pp. 1-19). ACM.

Stigliano, D., & Gentile, D. (2008). *Enseñar y aprender en grupos cooperativos: comunidades de diálogo y encuentro.* Buenos Aires: Novedades educativas.

Stolckel, A., Ries, K., Coccaro, N., Shriberg, E., Bates, R., Jurafsky, D., . . . Meteer, M. (2000). Dialogue act modeling for automatic tagging and recognition of conversational speech. *Computational linguistics*, 339-373.

Stout, R., Cannon-Bowers, J., Salas, E., & Milanovich, D. (1999). Planning, shared mental models, and coordinated performance: An empirical link is established. *Human Factors, 41*(1), 61-71.

Strauß, S., & Rummel, N. (2020). Promoting interaction in online distance education: designing, implementing and supporting collaborative learning. *Information and learning sciences*, 251-260.

Suchman, L. (1989). *Notes on computer support for cooperative work.* University of Jyväskylä.

Sun, C., Shute, V., Stewart, A., Yonehiro, J., Duran, N., & D'Mello, S. (2020). Towards a generalized competency model of collaborative problem solving. *Computers & Education*.

Ternité, T. (2009). Process lines: A product line approach designed for process model development. *Conference Proceedings of the EUROMICRO*, 173-180.

Van den Bossche, P., Gijselaers, W., Segers, M., Woltjer, G., & Kirschner, P. (2011). Team learning: building shared mental models. *Instructional Science, 39*(3), 283–301.

Varas Cortés, N. W. (2021). *Una técnica basada en prototipado rápido para favorecer el entendimiento compartido entre el cliente y el desarrollador.* Universidad de Chile.

Varas, N. (2021). *Una técnica basada en prototipado rápido para favorecer el entendimiento compartido entre el cliente y el desarrollador.* Santiago de Chile: Universidad de Chile, Facultad de ciencias físicas y matemáticas.

Vinagre Laranjeira, M. (2010). *Teoría y práctica del aprendizaje colaborativo asistido por ordenador.* Madrid: Sintesis.

Wanstreet , C., & Stein, D. (2011). Gender and Collaborative Knowledge Building in an Online Community of Inquiry. En *Encyclopedia of information communication technologies and adult education integration* (págs. 707-722). IGI Global.

Washizaki, H. (2006). Building Software Process Line Architectures from Bottom Up. *Product-Focused Software Process Improvement*, 415-421.

Webb, N. (1989). Peer interaction and learning in small groups. *International journal of Educational research, 13*(1), 21-39.

Webb, N., & Palincsar, A. (1996). *Group processes in the classroom.* Prentice Hall International.

Wegge, J., Roth, C., Neubach, B., Schmidt, K.-H., & Kanfer, R. (2008). Age and gender diversity as determinants of performance and health in a public organization: the role of task complexity and group size. *Journal of Applied Psychology, 93*(6), 1301.

Werner, C. (2021). Towards A Theory of Shared Understanding of Non-Functional Requirements in Continuous Software Engineering. *2021 IEEE 29th International Requirements Engineering Conference (RE)* (págs. 498-503). IEEE.

Werner, C., Shi Li, Z., Ernst, N., & Damian, D. (2020). The Lack of Shared Understanding of Non-Functional Requirements in Continuous Software Engineering: Accidental or Essential? *2020 IEEE 28th International Requirements Engineering Conference (RE)* (págs. 90-101). IEEE.

Whitehead, J. (2007). Collaboration in software engineering: A roadmap. *Future of Software Engineering (FOSE'07)* (págs. 214-225). IEEE.

Wildman, J., Salas, E., & Scott, C. (2014). Measuring cognition in teams: A cross-domain review. *Human factors*, 911-941.

Windeler, J., Maruping, L., Robert, L., & Riemenschneider, C. (2015). E-profiles, conflict, and shared understanding in distributed teams. *Journal of the Association for Information Systems*.

Wittgenstein, L. (1967). *Philosophische Untersuchungen. Philosophical Investigations.* Oxford : Blackwell.

Wohlin, C., Höst, M., & Henningsson, K. (2003). Empirical research methods in software engineering. *Empirical methods and studies in software engineering*, 7-23.

Xu, P. (2005). Knowledge Support in Software Process Tailoring. *Management Proceedings of the 38th Hawaii International Conference on System Sciences*, 87.

Yin, R. K. (1994). Discovering the future of the case study method in evaluation research. *1994 Published by Elsevier Inc.*, 283-290.

Zemel, A., & Çakir, M. (2009). Reading's work in VMT. *Studying virtual math teams*, 261-276.