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DISTRIBUTED TEAM COGNITION IN PROBLEM-SOLVING IN PROJECT MANAGEMENT CONTEXT

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“The end of a matter is better than its beginning; Patience of spirit is better than haughtiness of spirit (pride)".

Ecclesiastes 7:8 AMP, Holy Bible.

RESUMO

O comportamento dos membros da equipe de projetos é um fator importante para as organizações e deve ser gerenciado com estratégias específicas. A necessidade de cultivar, gerenciar, monitorar e de prever o desenvolvimento contínuo do comportamento humano que forma a base das *soft-skills* está se tornando cada vez mais evidente. Invariavelmente, o sucesso de um projeto depende do comportamento dos membros da equipe do projeto, que já devem ter bem resolvido os aspectos técnicos das *hard-skills*. Embora as habilidades técnicas sejam vitais e indispensáveis em qualquer metodologia considerada (ágil – tradicional – hibrida), fato é que a contribuição do comportamento dos membros da equipe pode superar a do conhecimento técnico. O objetivo dessa tese foi propor um modelo de cognição distribuída da equipe para a resolução de problemas de forma colaborativa no contexto de projetos. A pesquisa compreendeu o desenvolvimento de três estudos e um produto tecnico-tecnológico representado por um produto bibliográfico (CAPES GT 1). O primeiro estudo analisou como a cognição foi abordada na área de gerenciamento de projetos, por meio de uma revisão sistemática da literatura, com base em 138 artigos científicos retirados da SCOPUS e Web of Science, resultando em quatro categorias com dezesseis subcategorias e um modelo de cognição baseado nestas categorias. No segundo estudo, verificou-se como a cognição distribuída da equipe potencializa a resolução de problemas de forma colaborativa no contexto de projetos, por meio de uma pesquisa qualitativa e entrevistas em profundidade com uma amostra de 32 gerentes de projetos com experiência em métodos tradicionais e ágeis, atuando no Brasil e internacionalmente, resultando na confirmação que a cognição distribuída da equipe é significativa para a resolução colaborativa de problemas, e proposta de um modelo de cognição. No terceiro e último estudo, examinou-se a relação entre a cognição distribuída da equipe e a capacidade de resolução de problemas de forma colaborativa no contexto de projetos, por meio de uma pesquisa quantitativa com 417 respondentes o qual verificou a eficácia de um modelo de cognição distribuída da equipe no aumento da capacidade colaborativa de resolução de problemas, resultando na validação do modelo de cognição distribuída da equipe, bem como na identificação dos elementos considerados significativos para líderes de gerenciamento de projetos. O produto técnico-tecnológico produzido pretendeu construir uma ponte com o praticante, ao propor um produto bibliográfico com práticas e ferramentas para resolução colaborativa de problemas no contexto de projetos com o uso da cognição distribuída da equipe. Devido à sua natureza gerencial, o modelo de cognição distribuída da equipe e seus elementos propostos nesta tese podem ser aplicados a projetos em diferentes áreas, indústrias e métodos de abordagem. A aproximação da teoria da cognição distribuída da equipe em gerenciamento de projetos, a qual considera a capacidade de resolução colaborativa de problemas, se destaca como sendo a contribuição teórica. Como contribuição prática, se destaca a intenção de se propor um modelo de cognição distribuída da equipe, que pode ser aplicado nos setores profissional e/ou acadêmico e visa melhorar o trabalho colaborativo dos membros da equipe para a resolução de problemas no contexto de projetos. Esta pesquisa está alinhada com a linha de pesquisa 3: “Inovação em Projetos”, vinculada ao Programa de Pós-Graduação em Gestão de Projetos – PPGP UNINOVE, bem como essa tese também está alinhada com outras pesquisas vinculadas ao projetos-eixo “Economia Comportamental”. Adicionalmente, também está alinhada com a linha de pesquisa 2: “Gerenciamento de Projetos”, vinculada ao Programa de Pós-Graduação em Gestão de Projetos – PPGP UNINOVE, bem como essa tese também está alinhada com outras pesquisas vinculadas ao projetos-eixo “Gestão de Pessoas e o Gerenciamento de Projetos”.

Palavras-chave: Gerenciamento de Projetos. Cognição Distribuída; Estilo Cognitivo de Liderança; Relacionamento e Tensão com Stakeholders; Aprendizagem; Cognição no Desenvolvimento de Produtos.

ABSTRACT

The behaviour of project team-members is an important factor for organisations and should be appropriately managed. The need to cultivate, manage, monitor, and anticipate the continuous development of human behaviour that constitutes the foundation of soft-skills is becoming increasingly evident. Unquestionably, the success of a project depends on the human behaviour of the project team-members, who must already have well-resolved the technical aspects of hard-skills. Although technical skills are vital and indispensable in any methodology considered (agile - traditional - hybrid), the fact is that the contribution of team-members behaviour can surpass that of technical knowledge. This thesis aims to propose a distributed team cognition model for collaboratively problem-solving in the context of projects. The research encompassed the development of three studies and a technical-technological product represented by a bibliographic product (CAPES GT 1). The first study examined how cognition was approached in the project management area using an SLR based on 138 scientific articles extracted from SCOPUS and Web of Science, resulting four categories with sixteen subcategories and a cognition model based on these categories. The second study investigated how distributed team cognition enhances collaborative problem-solving in the context of projects through qualitative research and in-depth interviews with a sample of 32 project managers with experience in traditional and agile methods working in Brazil and internationally, resulting in the confirmation that distributed team cognition is significant for collaborative problem-solving. The third and final study examined the relationship between distributed team cognition and collaborative problem-solving in the context of projects, employing a quantitative study with 417 participants to assess the efficacy of a distributed team cognition model in enhancing collaborative problem-solving capacity, resulting in the validation of the distributed team cognition model as well as in the identification of important project management elements for project managers. The purpose of the technical-technological product was to establish a connection with practitioners by suggesting a bibliographic product containing methodologies and resources for collaboratively problem-solving challenges in the context of project management employing distributed team cognition. Due to its managerial nature, the distributed team cognition model and its proposed elements in this thesis can be applied to projects in many fields, industries, and approaches. The theory of distributed team cognition in project management, which emphasises the capacity for collaborative problem-solving, stands out as a significant theoretical contribution. As a practical contribution, the intention is to propose a model of distributed team cognition, which may be applied in professional and/or academic sectors, aiming to enhance collaborative work among team-members for problem-solving in project contexts. This research is aligned with research line 3: "Innovation in Projects", linked to the Postgraduate Programme in Project Management - PPGP UNINOVE, as well as this thesis is also aligned with other research linked to the project axis "Behavioural Economics". In addition, this research is aligned with the research line 2: "Project Management," linked to the Postgraduate Programme in Project Management - PPGP UNINOVE, as well as this thesis is also aligned with other research linked to the project axis "People Management and Project Management".

Keywords: Project Management. Distributed Team Cognition. Cognitive Style of Leadership. Stakeholder Relationship and Tension. Learning. Cognition in Product Development.

LIST OF ABREVIATIONS

MM	Methodological Matrix
PM	Project Manager
PMs	Project Managers
PTT	Technical-Technological Product
S1	Study 1
S2	Study 2
S3	Study 3
SLR	Systematic Literature Review

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SUMMARY

1. INTRODUCTION

Cognition is one of the basics of human behaviour, the great engine behind the behaviour (Rouleau *et al.*, 2021). Cognition can be defined as the mental processes associated with the acquisition of knowledge and understanding through thought, experience, and the human senses, and as such, involves specific functions, such as attention, knowledge building, memory, judgement, reasoning, problem-solving and decision-making, and language (Rouleau *et al.*, 2021; Seel, 2012). Cognition has two components that support and impact the decision-making process: a rational and an emotional component, which together can prescribe behaviour (Burstrom and Wilson, 2018; Pavez *et al.*, 2021). The emotional component of cognition modulates and guides rational cognition, in other words, the way we perceive the world, while the rational component processes all of this information (Brosch *et al.*, 2013).

Distributed team cognition can be defined as the resultant engine present of a group of individuals, which manifests itself through interactions between individuals, artefacts, technology and the environment, while also taking context into consideration (Flor and Hutchings, 1991; Hutchins, 1995). The connection between distributed team cognition and project management can result in a relevant combination that provides a significant basis of practises and tools geared toward human behaviour, sufficient to contribute to project management, particularly in projects with complex environments and contexts (Ahern *et al.*, 2014).

Comparatively, a review of the relevant literature reveals that while progress has been made in the field of research into project management methodologies, such as Kaufmann and Kock (2022) that examined the relationship among project management effort, complexity and profitability, Muñoz-Villamizar *et al.* (2021) that mapped the operations in project management, and Turner *et al.* (2013) that examined the interactions as influences and contributions between the nine schools of thought in project management; the nine schools considered were optimization, modelling, governance, behaviour, success, decision, process, and contingency, the same development has not occurred in the study of the cognitive behaviour of project team-members. In a particular context, it is essential to highlight the significance of the contribution to our understanding of human behaviour, which can be explained by the theory of distributed team cognition and is present in project management professionals (Rouleau *et al.*, 2021).

Evidence from earlier and more recent studies supports Hutchings' definition of the concept and explains specific phenomena associated with or correlating to the application of distributed team cognition in project management, such as: the cognitive diversity (Aggarwal and Woolleyb, 2019); conflicts resolution (Williams, 2019); communication and feedback (Habouba-Belinky and Parush, 2020; Smulders *et al.*, 2008); interpersonal trust (Pavez *et al.*, 2021); knowledge-exchange interactions (Liu *et al.*, 2022); social interaction (Liu *et al.*, 2022).

Considering the performance of the team in the context of projects through the lens of distributed team cognition, the literature cited in the previous paragraph reveals elements that point to the collaborative behaviour and the management capacity of the project manager as significant for the mitigation of tensions and problem resolution. Therefore, there is an opportunity in project management to investigate and propose a model of distributed team cognition that provides a foundation of practises and tools centred on human behaviour to contribute to project management in areas such as collaborative problem-solving.

1.1 PROBLEMATIZATION AND RESEARCH QUESTION

In an effort to create value and generate competitive advantages, project management field has been dedicated to addressing complexity, uncertainty, and ambiguity within the economic scenarios and its contexts in which organisations operate for the past six decades (Turner *et al.*, 2013). Until the mid-1980s, the project management field was largely devoted to engineering, construction, defence, and information technology challenges; only recently has it begun to develop research in administrative field and, consequently, behavioural domains (Turner *et al.*, 2013). In this sense, authors such as Kaufmann and Kock (2022) examined the relationship among project management effort, complexity and profitability. Furthermore, Muñoz-Villamizar *et al.* (2021) mapped the operations in project management, and Turner *et al.* (2013) examined the interactions as influences and contributions between the nine schools of thought in project management.

The study of behaviour through its driver, distributed team cognition, directly reflects the individual contribution abilities of individuals and is, therefore, highly relevant. In itself, cognition is essential for the functioning and maintenance of a purposeful life (Rebok *et al.*, 2020), and shared purposes have a direct correlation with teamwork engagement, which is an underexplored topic in the literature (Gersdorf-Van den Berg *et al.*, 2022). In this context, Lough *et al.* (2006) already postulated that social cognition is crucial for human interactions,

as social cognition refers to the capacity to comprehend the intentions and attitudes from others (NeuRA, 2022).

Understanding how distributed team cognition influence project management enables management to go beyond solely identifying how behavioural mechanics occurs, as it enables the proposal of models and solutions that allow anticipating events and, depending on the business segment in which the company operates, the proposal of training methodologies that prepare both the manager and the project team for day-today challenges. At that point, Sweeney *et al.* (2019) emphasise the significance of context in leadership challenges, which varies based on organisational objectives. And finally, the findings by Rebok *et al.* (2020) demonstrate that through standardised and systematic training in cognitive tasks, an individual's cognitive function can be enhanced in specific domains, including memory, attention, and executive function.

When examining team performance in the context of projects through the lens of distributed team cognition, authors such as Hoyle *et al.* (2020), Moradi *et al.* (2020), Norton (2020), Pavez *et al.* (2021), and Rouleau *et al.* (2021) indicate elements that point to the collaborative behaviour powered by teamwork engagement and management capacity of the project manager as being significant for the mitigation of tensions and resolution of problems. Collaborative performance and delivery in projects of value and/or results has been a new delivery approach, with its own operational environment that concentrate on the interaction and cooperation between project team-members and all other stakeholders (Bond-Barnard *et al.*, 2018; Moradi *et al.*, 2020). In this new working operational environment, the project manager is a main protagonist, qualified to make decisions regarding projects and the orchestration of the team-members that develop in business situations.

A context that is becoming increasingly complex makes it essential for the field of project management to identify the factors that influence individual human behaviour. The purpose of this research is to answer the following research question considering the information that has been presented thus far and a context that is becoming increasingly complex: **How does distributed team cognition enhances problem-solving in a project environment?**

1.2 OBJETICTIVES

General Objective

The general objective of this research is to propose a distributed team cognition model to enhance problem-solving in a project environment.

Specific Objectives

a) Investigate how cognition has been approached in the context of projects from literature.
b) Evaluate a distributed team cognition model for collaborative problem-solving in the context of projects based on project managers' view.
c) Examine the relationship between distributed team cognition and collaborative problem-solving capacity within the context of projects.

1.3 RESEARCH JUSTIFICATION

There is a large corpus of studies aimed at methodological research in project management, such as Kaufmann and Kock (2022) that examined the relationship among project management effort, complexity and profitability, Muñoz-Villamizar *et al.* (2021) that mapped the operations in project management, and Turner *et al.* (2013) examined the interactions as influences and contributions between the nine schools of thought in project management, however the same has not occurred with studies of behaviour in projects.

In this context, this study is justified, and a model of distributed team cognition is proposed, precisely because of the importance of understanding how aspects of cognition can influence the team-member and contribute to problem-solving in a collaborative way, in the context of projects. The proposed distributed team cognition model offers elements that promote the understanding of collaboration factors, and thus helps in proposing which of these factors should be developed and/or improved in the context of projects.

By analysing and expanding the understanding of a distributed team cognition theoretical model, this study contributes to the literature on how distributed team cognition improves collaborative problem-solving in the context of projects, and thus influences project performance and success. Its operational viability is due to the fact that, through exploratory research with experienced project managers, the practical model to be demonstrated is directly applicable in the daily operations of organisations of all types and business activities.

1.4 THESIS PROJECT STRUCTURE

The research for this thesis was intended to be conducted in three stages:

Step-1: The first step examined how cognition was approached in the project management area using an SLR. As expected, the findings from this step originated study-1 and served as the basis for step-2.

In turn, Step-2 investigated how distributed team cognition enhances collaborative problem-solving in the context of projects through qualitative research and in-depth interviews with a sample of 32 project managers with experience in traditional and agile methods working in Brazil and internationally. As expected, the findings from this step originated study-2 and served as the basis for step-3.

In Step-3, the final step, examined the relationship between distributed team cognition and collaborative problem-solving in the context of projects, employing a quantitative study with 417 participants to assess the efficacy of a distributed team cognition model in enhancing collaborative problem-solving capacity. As expected, the findings were sufficient to validate a model of distributed team cognition and served as a basis for the elaboration of the technical-technological product, which in this case is represented by a bibliographic product for project management practitioners presenting a brief framework to the community of practitioners in project management, consolidating in a practical manner the findings from the 3 studies comprising this thesis. The distributed team cognition model itself applied to the collaborative resolution of problems in the context of projects. Distributed team cognition has a significant impact on the performance and efficacy of project team-members, its effect can even unfold in catastrophic outcomes (Cooke *et al.*, 2013).

Methodological matrix of the thesis

Figure 1 describes the Methodological Matrix (MM) proposed by Da Costa *et al.* (2019) and aims to illustrate how the thesis is structured in accordance with the studies that comprise it. The MM is organised in accordance with the research question that guides the entire study and its research question. In addition, the justification for differentiating the studies based on their titles, research questions, and overall objectives is demonstrated. In addition, each of the studies provides a justification for the interdependence among the studies in the thesis, including the following information: the type of each study, the research method utilised, the data collection and analysis procedures, and the publication status.

Thesis Methodology Matrix

<table>
<tr><td>Central question of the thesis:</td><td colspan="2">How does distributed team cognition enhances problem-solving in a project environment?</td></tr>
<tr><td>General objective of the thesis:</td><td colspan="2">Propose a distributed team cognition model to enhance problem-solving in a project environment.</td></tr>
<tr><td>General justification of the thesis:</td><td colspan="2">There is a large body of research dedicated to methodological research in project management, but studies of behaviour in projects are limited. According to Rouleau et al. (2021), the brain contains cognitive and behavioural processes. Cognition as an antecedent, input process (Barrett, 2018; Rouleau et al., 2021), and behaviour, as an output process, which occurs after decision-making and is supported by distributed team cognition, that provides the opportunity to study problem-solving through its processes (Hutchins, 2000; Rogers, 1997).

Hutchins (1995) introduced the concept of studying cognition in the collective. Seel (2012), postulates about the abilities of the individual who acts in the collective and interacts with the environment. Detzen et al. (2018), postulates that behavioural integration at the team level is crucial for project success, and thus, Smulders et al. (2008), defines that collaboration prevents conflicts and favours collaboration. At this point, the findings by Poirier et al. (2017) reinforce the issue that the individual's cognitive determinants support collaborative actions, such as: requirements, expectations, intentions, incentives, and capabilities.

In this context, this study is justified by the proposition of a model of distributed team cognition, in justification of the importance of understanding how aspects of cognition can influence the team-member who works together, and contributes to problem-solving in a collaborative way, in the context of projects. The proposed distributed team cognition model offers indicators to be applied in understanding the collaboration factors, and thus help in proposing which of these factors should be developed and/or improved.</td></tr>
<tr><td colspan="2">Justification for the distinction of studies / articles</td><td>Justification of interdependence of studies / articles</td></tr>
<tr><td colspan="2">The thesis will be developed through the production of three research projects that will generate three articles. Each article serves a specific purpose/specific objective. The objective of Study-1/Article-1 is to evaluate how cognition has been approached in the context of project management. In Study-1/Article-1, a model resulting from the reviewed literature will be proposed; Study-2/Article-2 seeks for empirical evidence to verify the identified model of how distributed team cognition enhances problem resolution. At last, Study-3/Article-3 will conduct a quantitative study to consolidate the model identified in Study-1/Article-1 and tested/expanded in Study-2/Article-2.</td><td>The articles relate to the development of the technological product. The thesis presents the identification of a model of distributed team cognition for collaborative problem-solving in the context of projects, according to the scope of Study-1/Article-1, which will be validated/extended through an empirical and exploratory study in Study-2/Article-2. Study-3/Article-3 concludes with a quantitative study that aims to establish if the investigated model provides indicators that can be used to comprehend the collaboration factors and, thus, which of these factors should be developed and/or improved.</td></tr>
</table>

Thesis Methodology Matrix – continued

Study/Article	Title	Research Question	General Objective	Study Type	Research Method	Data Collection Procedures	Data Analysis Procedures	Publication Status
Study-1 / Article-1	TOWARDS OF COGNITION IN PROJECT MANAGEMENT	How does cognition been addressed in the context of projects?	Investigate how cognition has been addressed in the context of projects	Exploration	Qualitative	Systematic literature review: Elaboration of string and search in Web of Science and Scopus databases. Application of filters and eligibility criteria	Qualitative, through textual analysis of articles, based on a categorization process	Finished, and the results published in: Journal of Management & Technology
Study-2 / Article-2	DISTRIBUTED COGNITION AND PROBLEM-SOLVING IN PROJECT MANAGEMENT	How does distributed cognition enhances problem-solving in a project environment?	Investigate how distributed team cognition relates to collaborative problem-solving capacity in the area of project management	Exploration	Qualitative	Semi-structured interviews	Interview analysis	Finished, and the results published in: International Journal of Management Projects in Business
Study-3 / Article-3	A DISTRIBUTED TEAM COGNITION MODEL FOR PROBLEM-SOLVING IN PROJECT MANAGEMENT		Examine the relationship between distributed team cognition and collaborative problem-solving capacity within the context of projects	Explanatory	Quantitative	Survey: Google Forms	Multivariate analysis	Completed but not submitted.

Thesis Methodology Matrix – continued

Technical-Technological Product (PTT)	Product Name and Type	Description	Adherence	Impact	Applicability	Innovation	Complexity	Product Type
Product Detailing	Name: How does team cognition in behaviour enhance collaborative problem-solving in the context of project management? Type: Bibliographic Product	Propose a bibliographic product that includes practices and tools for collaborative problem-solving in the context of projects	High – the PTT is directly related to the program's line of work, as well as the research line in project management	High – the generated PTT will bring benefits in problem-solving and performance in projects, which will allow to reduce errors and delays in solving problems in projects	Medium – the generated PTT can be applied in the context of projects during the phases of the project management life cycle, both in solving problems in the planning phase and in the adversities that arise from project management	Low– the generated PTT presents unprecedented practices and tools for collaborative problem resolution in the context of projects	Medium – the generated PTT presents a high level of complexity as it involves different fields of knowledge and social actors for its elaboration and validation	Bibliographic Product

Figure 1. Thesis Methodology Matrix

Source(S). Elaborated by the author.

2. METHODOLOGICAL PROCEDURES

This doctoral thesis uses the format of a thesis by studies, which means that there is a sequence of research, methods, and techniques that were used in order to accomplish the goals that were proposed.

2.1 RESEARCH DESIGN

Given the relationship between the studies, it appears that the findings of both studies are complementary. This is asserted when stating that the studies' findings explicate how distributed team cognition improves problem-solving in a project environment. Figure 2 illustrates this study's design within the constraints of thesis research design by studies.

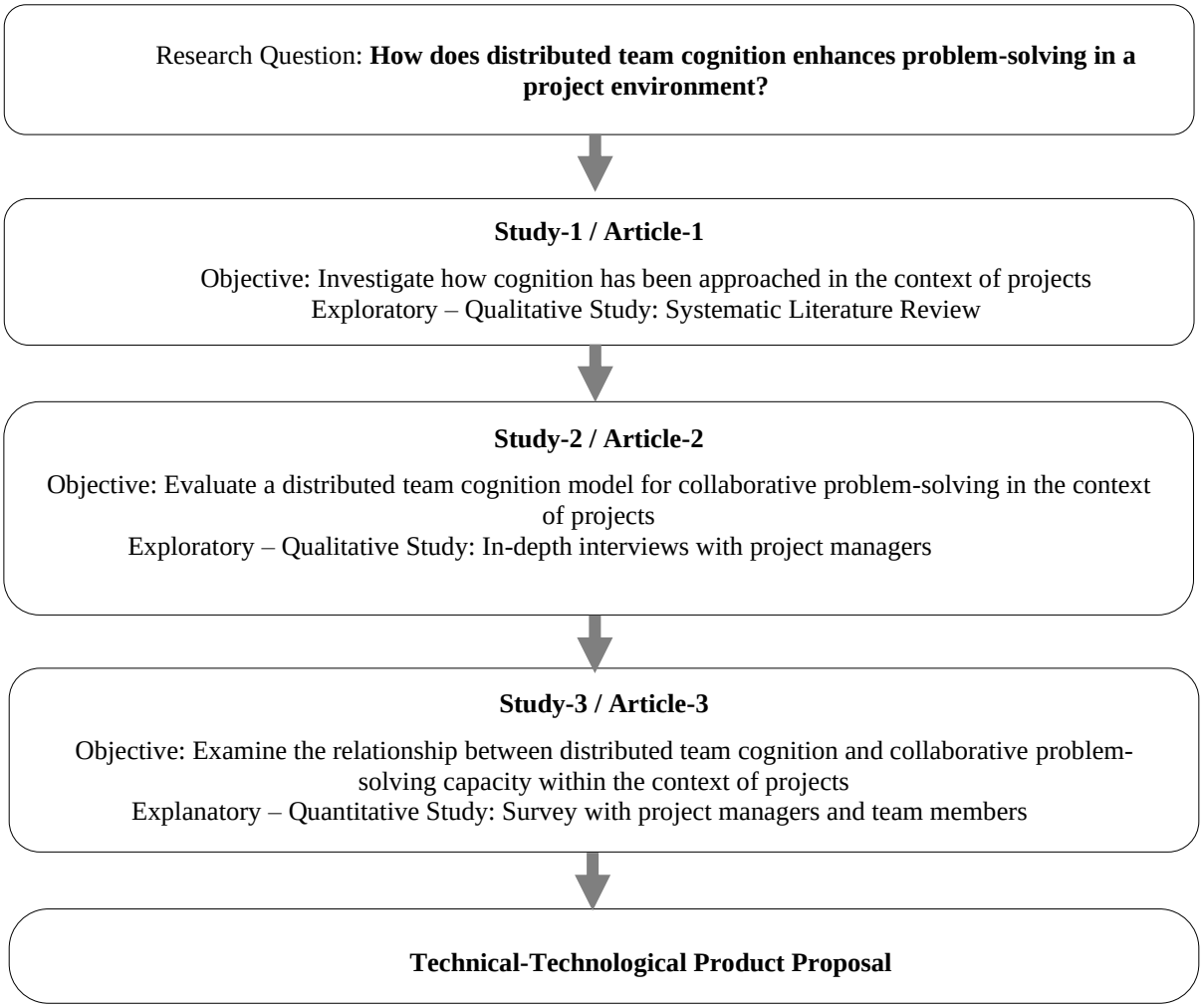


Figure 2. Thesis research design by studies

Source(s). Elaborated by the author.

3. STUDY-1: TOWARDS OF COGNITION IN PROJECT MANAGEMENT

The Study-1 provides a discussion by investigating how the topic of cognition has been approached in the area of project management. Previous research in the field of project management has investigated cognition at a specific level, with the goal of explaining some phenomenon or solving some particular issue, but without attempting to understand how this finding could be used to compose and explain human cognition in a comprehensive way, resulting in behaviour that could be applied usually in everyday project team life. For example, Shealy and Hu (2018) investigated cognition in decision-making in the context of trust and discovered that cognitive behaviour produces judgements and decisions that can overcome the human learning curve.

The results of this study were published in the Journal of Management & Technology, in Brazil, volume 23, n3, p. 85-127, made available in October 2023, and can be accessed according to link http://revistagt.fpl.emnuvens.com.br/get/article/view/2646/1452 and referenced in this document as Fernandes *et al.* (2023a).

Furthermore, Di Filippo *et al.* (2019) examined the cognition of project management and program management teams, linking the topic of cognition to the success of complex project management and leadership teams. Keeping the focus on project teams, Abankwa (2019) discovered that success in value delivery in complex projects is dependent on the level of adaptability of the team-members. Another point that emerges from this discussion is that in project collaboration and adaptability, due to factors such as uncertainty, there may be competitive behaviour that opposes collaborative behaviour, and Yue *et al.* (2019) investigated these points based on team cognition.

Understanding aspects such as adaptability, competition, and collaboration in project management, which includes environmental and contextual uncertainties, leads us downward the path of understanding which cognitive elements is important for project managers to position themselves and/or seek knowledge in order to anticipate and, thus, coordinate project circumstances. An instance of this is cognitive diversity, as studied by Aggarwal and Woolleyb (2019), which provides findings that cognitive diversity has a direct influence on the ability of team-members to promote creativity when considering team interactions and discussions, and as such, according to Niler *et al.* (2021), cognitive diversity is the most critical factor affecting team performance.

Individual cognition, as represented by each team-member, is the process of acquiring knowledge and understanding as a result of thought, experience, and human senses. The ability to perceive and respond, process, and comprehend information, store and retrieve information, and make decisions in order to generate appropriate responses to the environment and contexts that guide behaviour can be defined as cognition (Cambridge Cognition, 2015). Cognition is formed by genetic and environmental factors and improves constantly, adapting to the contexts in which individuals are placed and thus regulating behaviour throughout life (Fernandes and Cohen, 2020).

The study of team cognition permits us to learn about how cognition begins in the individual and manifests itself among team-members, the interaction of team-members with the environment, and the interaction of team-members with tools, artefacts, and society - and this holds true in both local and remote contexts (Sangwan *et al.*, 2020). The study of team cognition enables for the integration and analysis of human abilities, which consider the combinations of practises and thoughts with their mental states, and which invariably model human behaviour in the context of organisations (Schlindwein and Geppert, 2020).

In general, the Project Management Institute, relying on the PMBOK guide, does not address the topic of cognition in detail, but does raise some concerns, as stated in section three "Performing Integration" when referring to integration as a critical skill for project managers, with three levels: cognitive, context, and complexity (PMI, 2017). This is also true for the most recent edition, which mentions (meta)cognition exclusively in terms of critical thinking, "thinking about thinking and being aware of one's awareness", in addition to a brief discussion of confirmation bias (PMI, 2021).

There have undoubtedly been methodological advances in project management research; however, this has not occurred from the perspective of human behaviour, which seeks to comprehend project team-members' conduct. This study's goal is to investigate how cognition has been addressed in scientific publications on project management. Regardless of whether agile, traditional, or hybrid methods are used, the elements of cognition in human behaviour are expected to manifest in the same approach. This study describes a qualitative study based on the assumption that human behaviour is related to professional performance and, as a result, project success.

In light of the exposure and a human society that is becoming increasingly complex, this study describes how the literature on project management has addressed the topic of cognition. As a result, studies on project management under consideration were examined. To fulfil the proposal, this study employs the method of Systematic Literature Review in accordance with the model established by the researchers Pollock and Berge (2018). According to Pollock and Berge (2018), the Systematic Literature Review provides concrete answers to research questions through replicable modelling, as well as critical analysis and the use of primary data studies. In this sense, the authors establish a protocol that facilitates comprehension of both the research process and the method of documenting the research findings. This study contributes to a better understanding of how various aspects and elements of cognition can influence project teams professionally and help them solve project-related problems. In this context, the study clarifies the approach that cognition has received and proposes a model to be used in project teamwork.

3.1 Materials and method of Study-1

This study applied the methodology of Systematic Literature Review, as established by the researchers Pollock and Berge (2018), who recommend specific criteria for this type of methodology, to know: 1 – Identification; 2 – screening; 3 – eligibility; and 4 – included. In fact, these criteria consider specific steps such as: 1 – clarifying goals and objectives; 2 – conducting relevant research; 3 – collecting data; 4 – assessing the quality of the studies found; 5 – organising data; and 6 – interpreting study findings.

The first phase of this study was to clarify goals and objectives, which was accomplished by searching two research databases (SCOPUS and Web of Science) for scientific articles published in the field of project management. In both scientific bases, the string was (("cogniti*") AND ("project manager*"). This search was carried out using only words written in English, without regard for time, and only scientific publications were considered. Figure 1 illustrates the application of the research protocol.

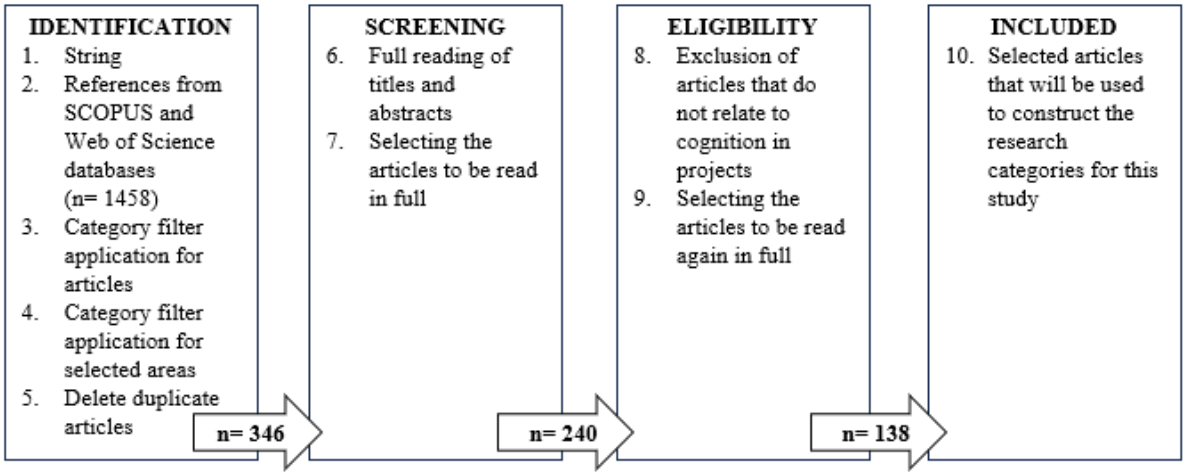


Figure 1. An illustrative representation of the research phases.

Source(s). Adapted by the author from the protocol of Pollock and Berge (2018), 2023.

The second phase – screening, involved the triage of discovered articles with the goal of locating articles that corresponded to the research objective. The third phase – eligibility, considered the selection of texts that corresponded to the subject of the study. It is worth noting that the inclusion criteria delineated scientific articles without a temporal filter, and on the subject of cognition in projects. As a result, articles from conferences, journals, and other areas of knowledge that had nothing dealing with project management were eliminated, as were articles written in languages other than Portuguese, English, and Spanish.

Although this study considered articles from the databases SCOPUS and Web of Science, the free software Ryyan was used in a preliminary approach to remove duplicate articles (available at www.rayyan.ai). Sequentially, the selected articles were analysed using the Microsoft Excel software, allowing for data analysis such as temporal review, and the material of the study was also analysed. Figure 2 illustrates the temporal analysis of article publications.

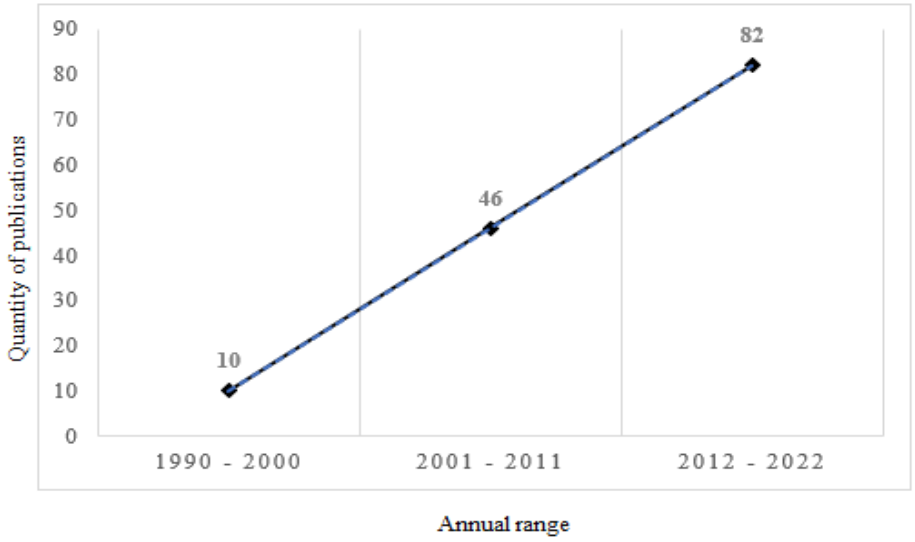


Figure 2. Temporal analysis of article publications (total of 138 articles).
Source(s). Elaborated by the author, 2023.

The final analysis phase – included, involved a total of 138 selected articles that were used to represent the subject of the study and achieve the objective that was suggested. It was possible to categorise the results and all identified content in this manner, using the Microsoft Excel software.

3.2 Analysis of results of Study-1

This section contains the results of database analysis. The first section maps the articles from the eligibility phase and the second section analyses and discusses the discovered categories.

3.2.1 Articles mapping

Following a review of the titles and abstracts, 138 articles were chosen based on eligibility criteria, including data from SCOPUS and Web of Science. These articles provided a useful framework for understanding how cognition was being addressed in project management. The articles considered ranged from 1992 to 2022 – as the final database consultation date was February 26, 2023. Figure 2 shows a temporal analysis of journal's articles, revealing a significant increase in the publication of articles on project management cognition over the last 20 years. Aside from the fact that more than 50% of all publications are from the last 10 years.

The analysis of the publications considered in this study reveals some trends in publication, as seen in the years 2002, 2008, 2012, and 2021, which may be explained by recent global economic crises and/or recessions. The fact is that economic crises, policy issues, and natural disasters pose a challenge to risk management and project management, and that the risk and resilience required are proportional to the size of the project (Yang *et al.*, 2022). As an example, the perceived peak in 2021 refers to the COVID-19 pandemic, with many studies addressing the topic, as the study by Yang *et al.* (2022). Following the mapping of the articles, the contents were examined and classified into four categories as shown below:

Categories found:

1. Distributed Team Cognition – with 66 articles (Ajayi *et al.*, 2016; Anvuur and Kumaraswamy, 2012; Bai and Qian, 2021; Bizarrias *et al.*, 2020; Bondar *et al.*, 2022; Buffinton *et al.*, 2002; Caughron and Mumford, 2008; Chak *et al.*, 2022; Chang, 2017; Chang *et al.*, 2013; Chen and Wei, 2009; Choi and Lee, 2018; Daniel *et al.*, 2022; Daniel and Daniel, 2018; Defranco-tommarello and Deek, 2004; Detzen *et al.*, 2018; Drury-Grogan, 2021; Dwivedula and Bredillet, 2010; Farooq *et al.*, 2018; Fellows and Liu, 2016; Forgues and Koskela, 2009; Gavrilova *et al.*, 2015; Habouba-Belinky and Parush, 2020; Han and Hovav, 2016; Han *et al.*, 2020; He, 2012; Hekkala *et al.*, 2018; Heldal *et al.*, 2020; Hilary and Menzly, 2006; Hsu *et al.*, 2020; Hyldegård, 2006; Julsrud, 2008; Leung *et al.*, 2002; Leung and Liu, 2003; Levitt *et al.*, 1999; Li *et al.*, 2022; Ligorio *et al.*, 2005; Lin *et al.*, 2012; Ling, 2002; Liu and Yetton, 2007; Loch, 2017; Moore, 2002; Patanakul, 2022; Pavez *et al.*, 2021; Rave *et al.*, 2022; Pietras and Coury, 1994; Poirier *et al.*, 2017; Robinson *et al.*, 2005; Sangwan *et al.*, 2020; Schultz *et al.*, 2021; Seus *et al.*, 2020; Small and Walker, 2011; Smith, 1992; Smulders *et al.*, 2008; Tuuli and Rowlinson, 2009; Um and Oh, 2021; Upadhayay and Guragin, 2014; Vaux and Kirk, 2018; Vlaar *et al.*, 2008; Wang *et al.*, 2021; Wei *et al.*, 2022; Weiss *et al.*, 2011; Williams, 2019; Williams *et al.*, 1995; Wilson *et al.*, 2007; Zhang *et al.*, 2021).

2. Cognitive Style of Leadership – with 30 articles (Ahmad *et al.*, 2022; Ahmadi Eftekhari *et al.*, 2022; Akman *et al.*, 2011; Aretoulis *et al.*, 2017; Cheung and Chuah, 2000; Du *et al.*, 2005; Edkins *et al.*, 2007; Elbanna, 2015; Espinosa *et al.*, 2006; Floris and Cuganesan, 2019; Friedman *et al.*, 1992; Gallagher *et al.*, 2015; Giannoccaro and Nair, 2016; Green, 2004; Hanna *et al.*, 2016; Haynes and Love, 2004; Kamhawi, 2008; Keane, 2022; Liu *et al.*, 2015; Maytorena *et al.*, 2007; Mubarak *et al.*, 2021; Prince, 1992;

Rashid and Boussabiane, 2021; Shipley and Johnson, 2009; Simon, 2006; Strang and Vajjhala, 2022; Thomas and Buckle-Henning, 2007; Tullett, 1996; Yang *et al.*, 2022; Zheng *et al.*, 2019).

3. Stakeholders' Relationship and Tension – with 24 articles (Barrett and Sutrisna, 2009; Burstrom and Wilson, 2018; Cheung *et al.*, 2011; Chua *et al.*, 2012; Collinge and Harty, 2014; Cuganesan and Floris, 2020; Flyvbjerg, 2021; Ghaleenoei *et al.*, 2021; Globerson, 1997; Guo *et al.*, 2021; Jenkin *et al.*, 2019; Kahvandi *et al.*, 2018; Kwak *et al.*, 2012; Loosemore *et al.*, 2020; Lu and Hao, 2013; Lu and Yan, 2016; Manu *et al.*, 2013; Qian *et al.*, 2020; Shand, 1994; Sperry and Jetter, 2019; Ugwu *et al.*, 2004; Wang *et al.*, 2021; Wong *et al.*, 2008; Yang *et al.*, 2022).
4. Learning – with 18 articles (Bhowmick *et al.*, 2015; Chan *et al.*, 2021; Chang *et al.*, 2021; Daradoumis *et al.*, 2002; Florén, 2005; Hanakawa *et al.*, 2002; Jääskä and Aaltonen, 2022; Khedhaouria *et al.*, 2017; Loosemore and Chandra, 2012; Majchrzak *et al.*, 2005; Marshall, 2008; Nembhard *et al.*, 2009; Sense, 2007; Sergeeva and Duryan, 2021; Smyth *et al.*, 2010; Song *et al.*, 2022; Whelton *et al.*, 2002; Wiewiora *et al.*, 2020).

The four identified categories are an abstraction of the readings of the selected articles that form the basis and foundation of this study. Each article was analysed and classified within the general interest, which was identified as the analysis progressed. Within this context, cognition has already proven to be a critical component of team performance and decision-making (Grand *et al.*, 2016). This is what justifies the search for a possible classification that exemplifies cognition in human interaction. The following section will go into each of these four categories in order to explain the study's findings.

3.2.2 Analysis and discussion of the discovered categories

The functioning of the human brain is divided into two processes: cognition and behaviour (Rouleau *et al.*, 2021). The cognition is responsible for the acquisition, storage, and processing of information, as well as the processes of thought, experience, and sensation that arise as a result of cognitive functions such as perception, attention, memory, problem-solving, decision-making, and language codification (Barrett, 2018; Rouleau *et al.*, 2021). The behaviour that is followed by the decision-making process acts as a feedback mechanism, materialising human desire (Rouleau *et al.*, 2021).

3.2.3 Distributed team cognition

People and artefacts interact within and outside of organisations in a sociocultural context, and processes distributed in time, space, and society, as well as their artefacts, identify how distributed cognition occurs (Hutchins, 2000; Rogers, 1997). Initially, Hutchins (1995), and later, as in the case of Hutchins (2000), proposed and developed a theory that seeks to explain cognition in a distributed manner, as something of a force resulting from interactions among individuals, artefacts, contexts, and society, departing from traditional cognition theory. As a result, it is important to understand the team-members' cognition and how this interaction operates.

With distributed cognition theory, it is possible to understand how team-members interact with the environment in order to complete their tasks, providing effective project management support (Seel, 2012). According to the findings of Hollan *et al.* (2000), cognitive processes can be organised and explained into three categories: social, temporal, and environmental. In practise, distributed cognition manifests itself when members of project teams interact with one another, involving time, environment and context, society, and its artefacts.

3.2.3.1 Collaborative behaviour

Collaboration is a behavioural skill that is the result of elements of personality and cognition (Ajayi *et al.*, 2016). In the context of collaboration, cognitive determinants are influenced by the expectations, intentions, and incentives that a team receives, in addition to the technical requirements (Poirier *et al.*, 2017). In terms of project activities, this refers to each team-member's ability to contribute, which includes comprehension, representation, and subordination to management (Ligorio *et al.*, 2005). An additional explanation to the subject of submission is that only individual understanding can reduce tensions, mitigate conflicts, facilitate collaboration, and produce achievements (Zhang *et al.*, 2021).

Collaboration is a skill that must be developed in the context of project management. When achieved, it allows for efficiency in conflict mitigation and resolution, which must be established through communication (Ligorio *et al.*, 2005). As such, it should be one of the most important and observed elements of management, with the development and application of specific strategies, such as collaborative planning, capable of enhancing shared perception (Schultz *et al.*, 2021) and mitigating cognitive distortion, which has an impact on cognitive

focus and reduces collaborative capacity (Sangwan *et al.*, 2020). In the ideal direction, collaborative leadership that effectively articulates an efficient communication process and is capable of managing expectations, hopes, and financial constraints has a greater impact on project team engagement, collaboration, and performance (Chak *et al.*, 2022).

3.2.3.2 Reasoning and problem-solving ability

Teams that are adaptable, communicate properly, and have a high rate of problem-solving are teams that have an elevated level of reasoning, are adaptable, communicate well, and are capable of managing conflicts (Detzen *et al.*, 2018; Smulders *et al.*, 2008). The ability to problem-solving necessitates the development of a shared mental model among team-members (Han and Hovav, 2016). The shared mental models consider previous experiences and represent the cognition of team-members through cognitive perception, which has a positive relationship with individual perception before being transformed into behaviour (Han and Hovav, 2016).

Decision-making will require a high level of shared cognition from the project team, which will consider communication and feedback recruited for conflict resolution (Habouba-Belinky and Parush, 2020; Smulders *et al.*, 2008), as well as a high level of cognitive integration - that which considers the result of rational and emotional cognition (Patanakul, 2022). Conflict can be caused by factors of internal or external order, such as cognitive, occupational, or individual stimuli (Williams, 2019), however, it can also be caused by tasks and contexts (Detzen *et al.*, 2018), which can impact on intentions of collaboration, communication, trust, and other emotional aspects (Vaux and Kirk, 2018), or even by cognitive differences, such as previous experiences (Hilary and Menzly, 2006).

3.2.3.3 Communication and collective interaction

Communication and teamwork improve relationships, supporting the idea that there is an evolution from the individual to the social level (Drury-Grogan, 2021). Motivation is one of the outcomes provided by formal and informal communication processes to project teams (Dwivedula and Bredillet, 2010). Communication ability aids in conflict resolution and raises team awareness, which has a positive impact on team performance and task execution (Dwivedula and Bredillet, 2010; Habouba-Belinky and Parush, 2020). Associated with the development of trust, they contribute to the effective problem-solving by raising morale and

motivation (Vaux and Kirk, 2018), which, in turn, considers the management of emotions in order to guarantee integrated work (Wang *et al.*, 2021; Menzly *et al.*, 2006).

3.2.3.4 Trust building

Trust building is composed of up of two parts: cognitive and emotional (Julsrud, 2008). In an organisational context, trust is impacted when project teams are unsure about how to interact and collaborate. Confidence is essential in knowledge sharing and is influenced by internal barriers and social norms in a given context (Han and Hovav, 2016). Trust building, which is composed of cognitive and affective components, is consolidated in the interactive relationships of team as well as in perception (Pavez *et al.*, 2021). When considering uncertain, complex, and unstable environments, trust and resilience are complementary components that have a positive relationship (Wei *et al.*, 2022).

3.2.3.5 Sociocognitive and knowledge building

Cognitive, contextual, and social factors all influence team-members' behaviour and experiences with cognitive and emotional order during the project's execution (Hyldegrd, 2006; Liu *et al.*, 2022). Informal relationships have an impact on task performance and personal commitment, lending credence to the notion that they improve knowledge sharing (Liu *et al.*, 2022). Sociocognitive problems, which differ depending on the context, decrease team efficiency (Forgues and Koskela, 2009). As previously stated, cognitive elements either enhance or constrain the construction of knowledge (Loch, 2017).

3.2.4 Cognitive style of leadership

Perceptions differ among team-members in terms of attribution of value, conceptualizations, and problem-solving behaviour (Asch and Witkin, 1948). As a result, cognition is represented by cognitive styles that can be classified as intuitive - field dependent, or analytical - field independent. Taking into account human interaction, one cognitive style may be more appropriate than another depending on the context and each individual's ability to adapt (Cuneo *et al.*, 2018).

3.2.4.1 Cognitive complexity

The ability of an individual to comprehend nuances and minor distinctions is referred to as cognitive complexity. The cognitive ability to distinguish explains how social elements are perceived as distinct, separate, or independent. The ability to integrate refers to how social

elements are perceived as similar, connected, or interdependent (Green, 2004). Cognitive complexity, cognitive differentiation, and cognitive integration all have a significant relationship with project performance (Green, 2004). The cognitive complexity is related to the role played by each team-member.

Human cognition and cognitive complexity can be developed through regular and continuous training, preferably through hands-on practise (Prince, 1992). The development of human cognition improves critical aspects of human behaviour such as energic, enthusiasm, assertiveness, and results-oriented, distinguishing professionals with high performance and delivery capacity (Hanna *et al.*, 2016).

Moral sensibility has a positive effect on behavioural responses in team management at the cognitive level. It is worth noting that moral sensibility refers to a team-member's ability to recognise the consequences of behaviour towards others based on moral considerations (Yang *et al.*, 2022). As a result, a high level of moral sensibility is associated with higher levels of attention and ability to provide more relevant feedback, as well as better dealing with self-perception (Yang *et al.*, 2022).

3.2.4.2 Ability to lead

Project management necessitates not only technical skills, but also cognitive and interpersonal abilities (Friedman *et al.*, 1992). The elements of effective management include cognitive style, age, education, and experience (Kamhawi, 2008; Mubarak *et al.*, 2021). As previously stated, motivation has a positive effect on cognition through significance, competence, and autonomy (Mubarak *et al.*, 2021). Personality traits are the most important factors influencing leadership capacity, followed by cognitive abilities, extrovertly, and openness (Aretoulis *et al.*, 2017). These factors are associated with cognitive and emotional complexity, increasing leadership capacity, and ensuring project success based on value delivery (Floris and Cuganesan, 2019).

The ability of a project manager to lead assumes both individual and social abilities. Individual abilities include knowledge and experience, interpersonal abilities and skills, and professionalism. The social skills take into account cognitive abilities, influence abilities, and emotional and teamwork aspects, with problem-solving and strategic thinking skills being the most important for leadership (Ahmadi Eftekhari *et al.*, 2022).

The high-performance management must be careful so that the negative effects of uncertain environments and high pressure do not result in a toxic management, manifested by coercive or abusive behaviour, compromising human and professional relationships with project team-members (Gallagher *et al.*, 2015). Finally, ethical, and transformative leadership is associated with cognitive ability, with a positive impact on integrated project teams, contributing to team psychological development and autonomy through social learning (Mubarak *et al.*, 2021), and transformative leadership (Ahmad *et al.*, 2022).

3.2.4.3 Conflicts and problem-solving

Conflict can manifest itself in project management in two ways: task-related or emotional (Cheung and Chuah, 2000). When it comes from tasks, conflict can be used to improve communication skills and project performance. Conflicts of emotion, on the other hand, result from emotional influences, personal traits, and individual beliefs, and can progress to cognitive-affective conflicts (Cheung and Chuah, 2000). Human behaviour is the result of cognition and emotion, and it takes into account the context and situational factors (Cheung and Chuah, 2000). Individual cognitive style influences how a person acquires and evaluates information and, as a result, develops problem-solving abilities and competencies (Shipley and Johnson, 2009).

Typically, cognitive styles are not adaptable to the type of problem; rather, an individual employs a cognitive style and mental models in a given situation, due to a cognitive style provides the ability to apply intelligence, knowledge, and problem-solving skills (Tullett, 1996). Collaborative learning benefits from cognitive style by encouraging self-reflection and enhancing the building of knowledge (Du *et al.*, 2005). As additional factors, it is necessary to pay attention to the context's complexity, which has a direct impact on intuition influenced by prior beliefs and knowledge, which ensures the team's reflexivity (Edkins *et al.*, 2007; Elbanna, 2015), and risk identification, where cognitive traits influence perception and behavioural attitudes (Maytorena *et al.*, 2007).

3.2.5 Learning

Individuals acquire knowledge based on their personal preferences. Each person has an individual method of learning for acquiring, processing, and retaining new information, which can be transformed into useful skills. "New information" refers to the process of expanding or shaping prior knowledge. Many factors can influence an individual's preferred learning approach, including the environment, contexts, circumstances, and timing (Hatami, 2013).

3.2.5.1 Cognitive learning

Improved learning is a direct result of an individual's cognitive structure, which takes into account interaction with the environment and previous experiences. Given that mental models are associated with meaning interpretation and development, cognitive learning makes use of them to reorganise and expand on acquired knowledge during activity (Bhowmick *et al.*, 2015). By reducing total individual cognitive load, collaborative learning outperforms individual learning. The collective's cognitive efforts aim to process the task's cognitive load by establishing mental representation affinity (Bhowmick *et al.*, 2015).

Individual learning is intricately linked to cognitive motivation, intuition, interpretation, integration, and the level of cognitive engagement, also known as the "need for cognition." Individuals with a high need for cognition tend to perform better even when faced with cognitive demands, according to research by Bhowmick *et al.* (2015) and Chan *et al.* (2021). Individuals with a high need for cognition also have a higher level of cognitive motivation, which reinforces the learning process capacity (Chan *et al.*, 2021). Individual cognition is enhanced in this context through reflection and the use of constructive feedback (Chang *et al.*, 2021).

Furthermore, the role of trust building, which includes both cognitive and emotional components, influences intuition and contributes significantly to the emotional and experiential aspects of learning (Smyth *et al.*, 2010). The research of Jääskä and Aaltonen (2022) provides an illustration of this phenomenon. According to Jääskä and Aaltonen's research, cognitive learning provides a greater degree of learning depth when compared to alternative methodologies, such as the game-based learning approach. This improved learning experience is attributed to games' more profound engagement, which influences learning and motivation through increased participant involvement. Such a learning mode is based on cognitive, affective-emotional, and sociocultural domains, emphasising its multifaceted nature.

3.2.5.2 The manager in learning

Management plays a crucial cognitive role in organisations' two-stage learning processes. To influence team-members' performance, managers first interpret external environmental factors and then interpret internally organisational contexts (Florén, 2005; Majchrzak *et al.*, 2005). Managers facilitate creativity, motivation, and collaboration while effectively managing time-related pressures (Khedhaouria *et al.*, 2017), and they strike a balance between encouraging collaboration and encouraging competitive dynamics (Nembhard *et al.*, 2009).

Furthermore, within the structure of situated cognition, the relationship between pre-existing cognitive schemas and organisational contexts is well-documented, providing profound insights into the realm of managerial and organisational cognition (Elsbach *et al.*, 2005).

3.2.5.3 Sociocognitive learning

Learning, according to the sociocognitive perspective, occurs through the convergence of individual mental models, as members come from a wide range of backgrounds, training, knowledge, and skills (Chang *et al.*, 2021). This may require a great deal of effort to give artefacts meaning through communication, interaction, and negotiation (Loosemore and Chandra, 2012). Individual cognition contributes to the organisational learning framework because behaviour is the result of the interaction of individual cognition and situational factors (Chang *et al.*, 2021; Loosemore and Chandra, 2012; Sense, 2007). Effective management can capitalise on cognitive style incompatibility in the development of team-based learning (Sense, 2007).

Diversity administration is crucial in developing a culture of learning and collaboration. Team-members can improve their learning and knowledge building in sociocognitive learning (and sharing) by minimising cognitive differences between mental models and stimulating perception (Chang *et al.*, 2021; Loosemore and Chandra, 2012). When cognitive conflict is resolved, learning occurs through collaboration (Chang *et al.*, 2021; Wiewiora *et al.*, 2020).

3.2.5.4 Organizational learning from projects

Learning in project management comes during project execution and as a result of project experience, and is positively related to cognitive processes, situation interpretation, and team integration (Chang *et al.*, 2021; Wiewiora *et al.*, 2020). In this process, project learning takes into account that team-members must develop to the point where they are capable of recognising the various environmental stimuli that have a personal and individual impact on each team-member, and that these stimuli will be used in the decision-making process before becoming a behaviour – team cognitive differences, and thus ensuring collaborative problem-solving (Chang *et al.*, 2021; Sergeeva and Duryan, 2021). According to Loosemore and Chandra (2012) and Maichrzak (2005), organisational culture influences learning in three ways:

1. Individual cognition – has a positive impact on how team-members interpret the environment and make (good) decisions.
2. Shared cognition – with a positive impact on the development of knowledge through perception (value attribution), effective behaviour, and problem-solving that sustain collaboration.
3. Explicit values – with a positive impact on the influence of beliefs and social norms.

3.2.6 Stakeholders' relationship and tension

The relationship between the project team and the parties involved can be tense, and it is therefore crucial to understand what dynamics are at work across the business. Essentially, what guides these relationships is related to the specifics of the value chain and the desired outcome for each stakeholder, which has an impact on the understanding of the shared principles and objectives of those who participate in achieving success (Freeman *et al.*, 2020).

3.2.6.1 Social capital

The social capital is formed by the combination of knowledge, expertise and skills manifested in the abilities of a project team in the context of projects. The development of social capital benefits from connections derived from shared values and beliefs, as well as peer norms, which are developed through leadership, influence, and experience (Chua *et al.*, 2012). The social capital is divided into three dimensions: structural, cognitive, and relational. The structural dimension takes into account prior experience that will be considered in order to maintain or create relationships (Chua *et al.*, 2012). From a cognitive dimension, consider the team's representations, interpretations, and meanings. The relational dimension considers the strength of a relationship as manifested by an individual's ability to develop a personal relationship from a professional relationship (Chua *et al.*, 2012).

The behaviour of each stakeholder class is influenced by perception - attribution of value and significance, and communication (Kwak *et al.*, 2012), affection, health, and well-being (physical and mental), cognitive abilities, personal and professional aspects of behaviour, and situational factors (Chua *et al.*, 2012; Loosemore *et al.*, 2020).

3.2.6.2 Cognitive involvement

The development of cognitive knowledge has a positive effect on shared understanding, communication, and the identification of project artefacts, and it is reinforced by comprehension, interpretation, and meaning attribution, which differs based on stakeholder

class (Collinge and Harty, 2014). The attribution of significance, artefacts, and involvement (essentially manifested through communication) may have an impact on the variability of comprehension during project phases (Jenkin *et al.*, 2019). In terms of stakeholder management, it is critical that project managers identify the appropriate stages of development for each stakeholder class (Kahvandi *et al.*, 2018), as well as relationship management, which has a direct impact on resilience and collaboration (Yang *et al.*, 2022).

3.2.6.3 Affective and cognitive trust

Trust building is a concept that can be formed by combining the rational and emotional dimensions. The rational dimension is represented by comprehension and understanding. The emotional dimension considers all emotional and affective aspects of the human being (Cheung *et al.*, 2011). The development of trust has a positive impact on collaboration, as it is required for the collaborative problem-solving, the development of communication processes, and the improvement of emotional relationships (Guo *et al.*, 2021). Each stakeholder class has its own set of interests and motivations, which can make trust building difficult (Wong *et al.*, 2008).

A relevant fact is that the ability to manage takes into account both rational and emotional dimensions in order to achieve excellence (Guo *et al.*, 2021). Trust building receives the impact of motivation, expectation, and the ability of taking risks in the face of uncertainty (Wong *et al.*, 2008). Both emotional and rational trust interrelate and have a positive effect on trust building, resulting in better cooperation and communication (Lu and Hao, 2013; Lu and Yan, 2016; Flyvbjerg, 2021).

3.2.6.4 Tension and cognition

Tenses also have two dimensions: rational and emotional (Burstrom and Wilson, 2018), which can be caused by cognitive differences among individuals, resulting in a lack of information and uncertainty, in addition to the fact that being raised from the emotional dimension increases the problem by raising the complexity and uncertainty (Burstrom and Wilson, 2018; Cuganesan and Floris, 2020). Cognitively, leadership ability correlates positively with mental models, such as the need to maintain team integration despite pressures from contrasts and contradictions (Cuganesan and Floris, 2020).

From the perspective of the project team, emotional tension has both positive and negative effects on value creation and engagement, taking into account the aspects of collaboration versus competition (Qian *et al.*, 2020). In this way, mental models influence

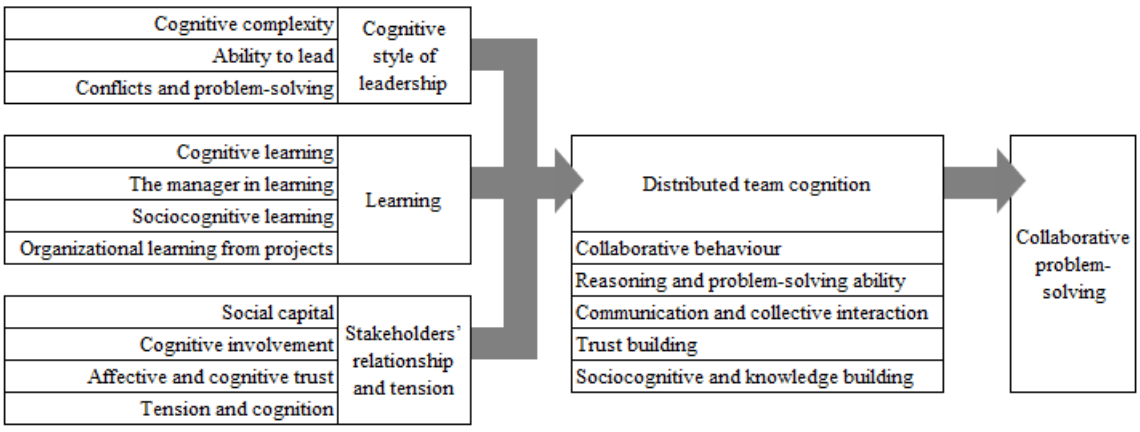
decision-making at all levels of management, project teams, and stakeholder groups (Cuganesan and Floris, 2020; Shand, 1994). As a result, understanding of perception, empathy, and engagement are critical in stakeholder management (Sperry and Jetter, 2019).

3.3 Conclusion and final considerations of Study-1

This study contributes to theory by investigating how the topic of cognition has been discussed in project management literature. The findings of this study point to 4 major categories and 16 subcategories. The aim of this study achieved through the presentation of the 4 categories (each with its own subcategory) and the presentation of a theoretical model of distributed team cognition with the objective of being applied in collaborative problem-solving in the context of projects.

Based on the mentioned categories, this study posits that Cognitive Leadership Style, Stakeholder Relationships and Tension, and Integrative Learning may serve as potential precursors to Distributed Team Cognition. Consequently, upon scrutinizing the subcategories of Distributed Team Cognition, we have unearthed evidence that Collaborative Behaviour, Collective Communication and Interaction, Trust Building, and Sociocognitive Knowledge Construction significantly contribute to Collaborative Problem-Solving, which, in turn, impacts decision-making and consequently leads to project value delivery and success. Figure 3 illustrates a distributed team cognition model for collaborative problem-solving in project management.

Figure 3. Model of distributed team cognition for collaborative problem-solving in project management.



Source(s). Elaborated by the author, 2023.

Based on the findings, this model proposes that distributed team cognition has positive effects on collaborative problem-solving and is the category that contributes the most to the achievement of the study's aim. Theoretical evidence supports the idea that a cognitive style of leadership, stakeholder relationship and tension, and integrative learning are precursors to distributed team cognition. In this context, some points are presented below in explanation and justification of the proposed model.

The interaction between integrative learning and distributed team cognition suggests that learning contributes positively and in a bidirectional manner to collaborative behaviour in the mechanism of learning to collaborate and collaborating to learn (Liu *et al.*, 2021). Given that collaborative behaviour is a direct result of personality traits and cognition (Ajayi *et al.*, 2016). Furthermore, this relationship suggests that there are positive effects for auto-reflexivity and collective knowledge creation (Du *et al.*, 2005), improvements in communication and collaborative interaction (Yap *et al.*, 2017), trust building, and knowledge sharing (Chang *et al.*, 2021; Loosemore and Chandra, 2012). By the way, trust building has a positive and bidirectional effect in terms of producing shared knowledge (Shealy and Hu, 2018).

The interaction between integrative learning and stakeholder relationship and tension demonstrates a positive relationship for the improvement of cognitive and emotional intelligence that can be accomplished through continuous and experiential training (Xiang *et al.*, 2016). In this sense, attribution of significance, project artefacts, and involvement achieved through communication processes can all be manifested by the project manager's ability to involve each class of stakeholders in the appropriate stages and manner (Jenkin *et al.*, 2019). In fact, managing stakeholder groups necessitates a high level of cognition and emotional control (Burstrom and Wilson, 2018; Cuganesan and Floris, 2020).

The interaction between integrative learning and cognitive style of leadership considers the manager's leadership capacity – cognitive and emotional-affective abilities, which is effectively related to collaborative processes. This approach to cognitive development has an impact on behaviour in areas such as enthusiasm, assertiveness, and results-oriented, distinguishing professionals based on performance (Hanna *et al.*, 2016). Learning in project management occurs primarily through the performance of traditional work practises and/or the introduction of new work practises (Chang *et al.*, 2021), and comes from three forms: project-based (Chang *et al.*, 2021; Wiewiora *et al.*, 2020), organizational-based (Chan *et al.*, 2021; Chang *et al.*, 2021), and interproject-based (Chang *et al.*, 2021). Furthermore, factors such as

age, cognitive style, experience, and education influence a project manager's ability to lead (Kamhawi, 2008; Mubarak *et al.*, 2021).

The interaction between leadership cognitive style and distributed team cognition reinforces the importance of management capacity in fostering collaborative behaviour and overcoming adversity (Sangwan *et al.*, 2020; Schultz *et al.*, 2021). As rationality is intertwined with affectivity and emotion (Chak *et al.*, 2022), management capacity is critical in fostering hope. Effective communication and collective interaction involve mental models that promote the perception of its importance in behaviour, as well as directed communication capable of instructing, empowering, collaborating, and effectively mitigating conflicts (Han and Hovav, 2016; Detzen *et al.*, 2018). Project managers must motivate and empower team-members to maintain self-managed communication and feedback channels, as consistent practise improves relationships, increases cognition, moderates emotionality, and reduces conflicts (Dwivedula and Bredillet, 2010; Habouba-Belinky and Parush, 2020; Drury-Grogan, 2021).

The manager must be the one who promotes trust building by continually taking the first step, leading by example, ensuring experience, and thus contributing to the learning curve (Han and Hovav, 2016; Pavez *et al.*, 2021). Knowledge building, on the other hand, considers the influence of cognition and emotional experiences in influencing behaviour through context and social factors during project execution (Hyldegrd, 2006; Liu *et al.*, 2022). In this sense, the project manager must act in such a way that sufficient strategies are employed to manage potential cognitive bias in team-members (Loch, 2017), moderating rational relationships (Chang *et al.*, 2013; Small and Walker, 2011), as well as emotional relationships (Patanakul, 2022), towards the end that, in fact, teamwork leads to knowledge building (Chang *et al.*, 2013; Small and Walker, 2011).

The interaction between cognitive style of leadership style and stakeholder relationship and tension reinforces the significance of the requirement for project managers to be aware of how to deal with differences in relationships that use relational and emotional components, primarily integrating competencies, in stakeholder classes (Burstrom and Wilson, 2018; Cuganesan and Floris, 2020). Cognition in behaviour is complex and considers the dimension of emotions-affectivity, given that the way in which human beings create their own representations of reality and assign meaning, in an equivalent way, is personal, with people choosing how they will learn something new based on their preferences and capabilities (Hatami, 2013; Chua *et al.*, 2012). As previously stated, collaborative behaviour is one of

aspects of trait of personality (Ajayi *et al.*, 2016), and personality is influenced by expectations, intentions, and incentives in the context of collaboration (Poirier *et al.*, 2017). In such circumstances, the manager has to achieve a balance between cognitive and emotional competencies in order to lead. Recognising that in human interaction, one cognitive style may be more beneficial than another, depending on the context and the activities to be developed (Cuneo *et al.*, 2018).

The interaction between stakeholder relationship and tension and distributed team cognition may include into account the involvement that is constructed by perception and communication processes (Collinge and Harty, 2014; Loosemore *et al.*, 2020), as well as aspects of involvement in conflict resolution (Williams, 2019), which affects cognition and collaborative, communication, trust, and moral efforts (Vaux and Kirk, 2018). Tension affects all stakeholder classes, from project team to entire organisation (Burstrom and Wilson, 2018; Cuganesan and Floris, 2020). On this basis, the project manager should employ strategies that appropriately manage each stakeholder class (Kahvandi *et al.*, 2018), establish a shared and collaborative vision (Jenkin *et al.*, 2019), trust building between each stakeholder class, project management, and project team (Julsrud, 2008; Han and Horav, 2016; Pavez *et al.*, 2021), and manage cognitive-emotional relationships (Cheung *et al.*, 2011; Guo *et al.*, 2022). Lastly, leadership must choose strategies capable of controlling rivalry and promoting resilience (Yang *et al.*, 2022; Qian *et al.*, 2022), making appropriate use of prior experience (Chua *et al.*, 2012; Yang *et al.*, 2022), and promoting an environment with a shared vision, trust, and capable of creating and sharing knowledge.

The interaction between distributed team cognition and collaborative problem-solving includes components such as individual attention and perception, and level of consciousness (Barrett, 2018; Rouleau *et al.*, 2021). High efficiency in collaborative problem-solving arises from individual behaviour and is reinforced by team capacity (Drury-Grogan, 2021). Effective leaders with effective teams make better decisions and achieve higher rates of problem-solving (Daniel and Daniel, 2018; Han and Horav, 2016).

The study's conclusion suggests that the capacity to collaborative problem-solving is directly related to distributed team cognition; that is, an increase in distributed team cognition has a proportional and positive effect on the capacity to collaborative problem-solving in the project environment. Given that the environment in projects is associated with factors such as complexity (Hekkala *et al.*, 2018), uncertainty and high pressure (Gallagher *et al.*, 2015),

instability and ambiguity (Sergeeva and Duryan, 2021), and technologically unstable (Dayan and Di Benedetto, 2011). The findings indicate that this is the most important category among them.

4. STUDY-2: DISTRIBUTED COGNITION AND PROBLEM-SOLVING IN PROJECT MANAGEMENT

The Study-2 investigates how distributed team cognition relates to collaborative problem-solving capacity in the area of project management. As an illustration, the study by Shealy and Hu (2018) linked cognition with decision-making in terms of trust. Abankwa (2019) demonstrated the significance of team adaptability for the success of complex projects. Aggarwal and Woolleyb (2019) found that cognitive diversity affects the team's creative capacity, and the study by Drury-Grogan (2021) that correlated communication and collective interaction.

The results of this study were published in the International Journal of Management Projects in Business, in United Kingdom, made available in September 2023, and can be accessed according to link https://www.emerald.com/insight/content/doi/10.1108/IJMPB-05-2023-0100/full/html. This study is referred to in this thesis as Fernandes *et al.* (2023b).

Bond-Barnard *et al*. (2018) demonstrated the relationship between trust and collaboration in project teams based on related research. The research conducted by Poirier *et al.* (2017) demonstrates that the cognitive factors of an individual, such as requirements, expectations, intentions, incentives, and talents, contribute to the achievement of collaborative behaviour. Aggarwal and Woolleyb (2019) discuss that the cognitive diversity of team-members influences the collective cognition by influencing how information is organised and distributed within the team and, consequently, the collective delivery capacity for creativity.

According to Schlindwein and Geppert (2020), approaching the topic of cognition entails analysing issues regarding the human abilities, which include the sets of practises and thoughts along with their mental states that influence individual human behaviour, in the context of business. Although research in the field of project management has advanced in methodological aspects, many opportunities still exist for advances on correlating the human behaviour of team-members.

The purpose of this study is to contribute to the understanding of human behaviour, which can be explained by the concepts of distributed cognition and is present in project management professionals. This study describes a qualitative investigation based on the premise that distributed cognition has a significant relationship with the performance of project team professionals. This study seeks to answer the following research question: **How does distributed cognition enhances problem-solving in a project environment?** This question

arises from a context that is becoming increasingly complex, making it essential for the project management field to identify the factors that influence individual human behaviour.

To answer the research question, a qualitative research strategy and in-depth interviews with a sample of 32 project managers were employed. The topic of cognition in projects is in the early stages of publication, with a high research potential, due to the need to learn more about the impact of distributed cognition on the behaviour that shapes human beings in projects, in addition to the possibility of contributing to the dissemination of knowledge in the project environment.

This study contributes to the literature on how distributed cognition enhances collaborative problem-solving in the context of projects, and thus impacts project performance and success, by analysing and expanding the understanding of a distributed cognition theoretical model. This study is divided into seven sections. This was the introduction; the subsequent sessions will cover the theoretical background, methodology, results presentation, discussion, conclusion and final considerations, and references.

4.1 Theoretical background of Study-2

This section presents the concepts relating to the three research constructs: Problem-solving in the context of projects; distributed cognition in the project team; distributed cognition in problem-solving in the context of projects.

4.1.1 Problem-solving in the context of projects

In the context of projects, problem-solving is mandatory, and regardless of whether traditional or agile methods are considered, there will always be a standard process, a method with its tools, sufficient to improve the chances of success if applied correctly (Drury-Grogan, 2021; Ribeiro, 2021). Thus, the context can be exemplified by everything that can exert a constraining force on problem-solving without directly interfering with the problems (Sangwan, 2020).

According to Ahern *et al*. (2014), projects have different levels of complexity and uncertainty, as demonstrated by occurrence and impact, as also posit by Cleden (2009) model. In addition, the inputs and/or outputs of the project may not be fully known and/or explored, which can be largely attributed to the external environment's volatility. Thus, complex projects cannot be completely specified in advance. Project management must develop a learning strategy for applying knowledge to solve complex problems that takes into account tacit knowledge, which is continuously fed by lessons learned from and between projects, resulting

in emerging knowledge (Hartmann and Dorée, 2015). As the complexity and uncertainty of a problem varies, different problem-solving strategies based on the problem domain are required (Ahern *et al.*, 2014).

It is important to highlight that the field of project management distinguishes itself from other disciplines by concentrating on multidisciplinary teams and the collaborative engagement of stakeholders in problem-solving activities (Urton and Murray, 2021). Currently, the team-members multidisciplinary backgrounds contribute to a diverse range of competences set and knowledge for problem-solving. However, this diversity can also present challenges to collaboration in various project contexts, which is significant for project success (LaFrance *et al.*, 2019; Urton and Murray, 2021).

4.1.2 Distributed cognition in the project team

Cognition can be defined as the process of acquiring knowledge and comprehension through the individual's thinking, experience, and senses. Consequently, the mental processes associated with cognition refer to the capacity to perceive and react, process, and comprehend, store and retrieve information, and make decisions in order to generate appropriate responses to the environment that will guide behaviour (Cambridge Cognition, 2015; Kiely, 2014). Muhammedjanovna (2021) argues that perception is relevant to cognition because an individual's mental quality is formed by intuition and perception. In contrast, intuition-based processes are more efficient and less dependent on cognition (Patterson, 2017). In this context, a decision-making process employs both intuition and perception as cognitive processes.

Hutchins (1995) relates on distributed cognition as a phenomenon that is explained by the interactions between people, the artefacts they use, and the work environment, which is also represented by context. The concept of distributed cognition supports the notion that it is possible to comprehend how team-members interact with the environment in order to complete a given task (Seel, 2012). Hollan *et al*. (2000) posit that mandatory distributed cognitive processes occur in three ways:

1. Distributed among members of a social group.
2. Distributed over time.
3. Coordinating between materials or structures in the environment.

The significance of communication and knowledge sharing within distributed cognition becomes evident through the examination of multidisciplinary teams engaged in collaborative

problem-solving, given that proximity and relationship promote cognitive proximity, knowledge exchange, development of ideas, and mutual learning (LaFrance *et al.*, 2019).

4.1.3 Distributed cognition in problem-solving in the context of projects

According to Detzen *et al*. (2018), behavioural integration at the team level is essential for project success. In this regard, Smulders *et al*. (2008) state that collaboration mitigates conflict situations, and that prior experience combined with training affects cognition and conflict resolution (Hilary and Menzly, 2006). Poirier *et al.* (2017) reinforce that cognitive factor, such as requirements, expectations, intentions, incentives, and talents, play a role in the achievement of collaborative behaviour. Recent evidence indicates that the cognitive diversity of team-members influences the collective cognition by influencing how information is organised and distributed within the team and, consequently, the collective delivery capacity for creativity (Aggarwal and Woolleyb, 2019).

To achieve a team structure focused on reasoning and problem-solving, it will be necessary to invest in adaptable, communicative, and conflict management capable teams (Detzen *et al*., 2018; Smulders *et al.*, 2008). Teams that develop the capacity for communication and feedback increase distributed cognition – of the collective – and are consequently more likely to perform tasks more effectively and reduce bad conflicts (Habouba-Belinky and Parush, 2020; Smulders *et al*., 2008). Conflict has different representations and origins, internal or external, and can be triggered by factors such as: from the tasks or the individual (Williams, 2019); Tasks and contexts (Detzen *et al.*, 2018) – directly affects cognition and collaboration efforts; Communication, trust and morale (Vaux and Kirk, 2018); Cognitive differences that can result from the association of previous experiences and lead to conflicts (Hilary and Menzly, 2006).

The distributed team cognition established by Hutchins (1995), demonstrates that cognitive and behavioural processes are related to how individuals interact with one another and with their environment and context (Hutchins, 2000). The brain, according to Rouleau *et al.* (2021), possesses cognitive and behavioural processes. Cognition as an antecedent, which acts as an input process (Barrett, 2018; Rouleau *et al.*, 2021), and behaviour, as an output process, which occurs after decision-making and is supported by distributed team cognition, which provides the opportunity to study problem-solving through its processes (Hutchins, 2000; Rogers, 1997). The unit of analysis in this study of distributed cognition transcends the capabilities of the individual, which distinguishes it from other theories of behaviour. Thus, it

considers explaining the resulting interactions between individuals, the artefacts they use, and the work environment, which is even represented by context (Hutchins, 1995, 2000).

Within the distributed team cognition study range in project management, studies correlate collaborative behaviour issues (Poirier *et al*., 2017; Zhang *et al.*, 2021); collective communication and interaction (Drury-Grogan, 2021; Wang *et al.*, 2021); trust building (Han and Hovav, 2016; Pavez *et al.*, 2021), and social cognition and knowledge building (Hyldegård, 2006; Liu *et al*., 2022). Still in the reasoning, if on the one hand the distributed team cognition can be used to explain cognitive events within the project team, there are proposed antecedents that relate the leadership capacity of the project manager (PM), as expressed by questions of the cognitive style of leadership, stakeholders' relationship and tension, and integrated learning as distributed team cognition support factors.

Regarding cognitive style of leadership, Cuneo *et al*. (2018) indicate that in human interaction, one cognitive style may be more adaptive than another – considered more appropriate, depending on the context. Collinge and Harty (2014) emphasise that stakeholder engagement takes place through communication and the creation of project artefacts. Jenkin *et al.* (2019) demonstrate that stakeholders' understandings can change over time, both within and between projects. This is due to cognitive processes, such as meaning attribution, artefacts – such as planning – and communication and artefacts. Involving and integrating stakeholders in the proper phases of a project increases its probability of success (Kahvandi *et al.*, 2018).

Lastly, integrated learning supports the model by contributing to the understanding that learning occurs in projects – the improvement of human learning can be the result of an individual's cognitive structure, which also takes into consideration the interaction with the environment (Bhowmick *et al.*, 2015). Thus, on the one hand, multidisciplinary is advantageous because it provides many opportunities for collective interaction, which can generate trust and corroborate collaborative behaviour enough to mitigate conflicts, in the team's performance for the collaborative problem-solving, primarily in the direction of directed communication, then it is important to highlight what it encompasses distributed cognition that can potentialize the collaborative problem-solving.

4.2 Methodology of Study-2

4.2.1 Research context and design of study 2

To answer the research question and achieve the research objective, qualitative research methods and in-depth interviews were employed. A research protocol comprising literature-extracted items was developed for this objective. A pre-test interview was conducted sequentially, which served as an initial reference before being discarded. As recommended by studies by Dilley (2000) and Silva (2022), it was possible to observe important aspects such as the location, interviewee, events involved, and the process during the interviews. The surveys were subjected to semantic and content analysis, which allowed the research objective to be attained. In the "tell me more" strategy, the instrument's guiding questions were used to initiate the conversation, and efforts were made to keep the interviewees discussing the topic. On this basis, it was possible to extract the elements required for data analysis. Thus, more important than the guiding questions initially created, the content of the discussion to be objectified. In this sense, the search is for saturation in the conversation during the in-depth interviews to understand the “why” and “how” the phenomena occur.

The strategy for selecting the sample was based snowball to access project managers qualified to interviews, who had a solid reputation, were experienced, and worked for reputable companies, with a gender balance, being selected. This choice was limited by the fact that only project managers were interviewed for this survey. The sample was defined by the selection of 32 project managers considering the selection criteria as shown below.

Sample selection criteria:

1. With experience as a project manager.
2. Any gender and age.
3. From any locality.
4. With experience in technology company.
5. Used to complex context and large/mega projects.
6. With experience in both methodologies from traditional/waterfall to agile.
7. With experience in local and international projects.

Furthermore, Table 1 describes the sample by gender, age, and years of experience in the field of project management.

Table 1 – Overview of Interviewee Characteristics

Interviewee	Gender	Age [yrs.]	Experience [yrs.]
PM-1	Male	41	20
PM-2	Female	39	15
PM-3	Female	41	27
PM-4	Female	37	19
PM-5	Male	58	33
PM-6	Male	38	15
PM-7	Male	57	39
PM-8	Female	36	17
PM-9	Female	40	11
PM-10	Male	57	37
PM-11	Male	39	19
PM-12	Female	38	17
PM-13	Female	29	5
PM-14	Male	40	14
PM-15	Male	41	24
PM-16	Male	47	24
PM-17	Female	27	9
PM-18	Female	51	24
PM-19	Male	48	27
PM-20	Male	50	23
PM-21	Female	29	6
PM-22	Female	40	25
PM-23	Male	46	27
PM-24	Female	54	30
PM-25	Male	55	30
PM-26	Female	27	5
PM-27	Female	25	2
PM-28	Female	40	18
PM-29	Female	28	6
PM-30	Male	46	21
PM-31	Female	45	24
PM-32	Female	56	34

Source: Elaborated by the author, 2023.

The sample consisted of 32 project managers, 18 women (aged between 25 and 56 years, median= 38.5 years; and experience median= 17.0 years) and 14 men (aged between 38 and 58 years, median= 46.5 years; and median experience = 24.0 years), working with large/mega technology projects, mostly in the banking, pharmaceutical, hospital, energy, and industrial automation segments.

As a research instrument, a script of questions for conducting and guiding the in-depth interviews was developed based on the conceptual framework of this study, as illustrated below. The analysis categories presented drive the conversation to allow discussion and identification of each behaviour in the speech context of interviewees.

Relationship between analysis category, reference authors, research question and observation unit:

- Cognitive Style of Leadership (category):
    - Description: Project managers cognitive style take account that exist differences in how people perceive, think, make judgments, and make decisions (Asch and Witkin, 1948; Weissenberg and Gruenfeld, 1966; Green, 2004; Hanna *et al.* ,2016; Cuneo *et al*., 2018).
    - Observation unit: Holistic or serialist behaviour, impulsive or reflexive thinking, divergent or convergent thinking, and field dependent style or field independent style.
- Stakeholders' Relationship and Tension (category):
    - Description; Relationship of stakeholders in projects considering the key issues of communication, engagement, trust building and tension management (Collinge and Harty, 2014; Lu and Yan, 2016; Burstrom and Wilson, 2018; Kahvandi *et al*., 2018; Jenkin *et al*., 2019; Sperry and Jetter, 2019; Cuganesan and Floris, 2020; Qian *et al*., 2020; Guo *et al*., 2021).
    - Observation unit: Presence or absent to communication, engagement, trust building and tension management.
- Integrative Learning (category):
    - Description: The term integrative learning adheres to the proposal of this experimental study since integrative learning considers the direct connection between conceptual and experiential learning (Florén, 2005); Sense, 2007; Smyth *et al*., 2010; Hatami, 2013; Bhowmick *et al*., 2015; Wiewiora *et al*., 2020; Chan *et al*., 2021).
    - Observation unit: Most biased among the four styles: accommodator, assimilator, convergent or divergent.

- Distributed Team Cognition (category):
    - Description: Distributed team cognition occurs through the interaction between (Hutchins, 1995; Rogers, 1997; Hutchins, 2000; Hollan *et al*., 2000; Seel, 2012).
    - Observation unit: Presence or absence of collaborative behaviour, communication and collective interaction, trust building, and social interaction and knowledge building.
- Collaborative Behaviour (category):
    - Description: Considering the role of the project team in the project manager's view, how does the collaborative behaviour occur (Ligorio *et al*., 2005; Ajayi *et al*., 2016; Poirier *et al*., 2017; Sangwan *et al*., 2020; Schultz *et al*., 2021; Zhang *et al*., 2021).
    - Observation unit: Presence or absence of collaborative behaviour.
- Communication and Collective Interaction (category):
    - Description: Considering the role of the project team in the project manager's view, how does collective interaction and directed communication occur (Dwivedula and Bredillet, 2010; Vaux and Kirk, 2018; Habouba-Belinky and Parush, 2020; Drury-Grogan, 2021; Wang *et al*., 2021).
    - Observation unit: Presence or absence of communication and collective interaction.
- Trust Building (category):
    - Description: Considering the role of the project team in the project manager's view, how does the trust building in the cognitive and behavioural components occur (Lin *et al*., 2012; Lu and Hao, 2013; Han and Hovav, 2016; Lu and Yan, 2016; Vaux and Kirk, 2018; Guo *et al*., 2021; Flyvbjerg, 2021; Pavez *et al*., 2021).
    - Observation unit: Presence or absence of trust building.

- Sociocognitive and Knowledge Building (category):
    - Description: Considering the role of the project team in the project manager's view, how does social interaction and knowledge construction occur (Hyldegård, 2006; Forgues and Koskela, 2009; Liu *et al*., 2022; Loosemore and Chandra, 2012; Loch, 2017; Chang *et al*., 2021; Chang *et al*., 2013; Small and Walker, 2011).
    - Observation unit: Presence or absence of social interaction and knowledge building.
- Sociocognitive and Knowledge Building (category):
    - Description: This category aims to understand how problem-solving in the collaborative environment occurs (Hilary and Menzly, 2006; Smulders *et al*., 2008; Han and Hovav, 2016; Detzen *et al*., 2018; Vaux and Kirk, 2018; Williams, 2019; Habouba-Belinky and Parush, 2020).
    - Observation unit: Presence or absence of collaborative problem-solving.

The research instrument was developed as stated above. Each guiding question was developed based on the theory of these studies and will be better explored by conducting the 32 field interviews.

4.2.2 Data Collection of study 2

The interviews were conducted virtually using the Google Meet tool and were scheduled beforehand according to the interviewer and interviewee's availability. Between June and July of 2022, an interview was conducted with each respondent, lasting an average of 45 minutes. The interviews were conducted using audio, video, and automatic transcription tools, accessible via an automatic browser plug-in, and each of the 32 sessions was recorded and stored in Google Recordings folder for videos and Google Transcription folder for automatic text transcripts, with each interviewee's permission.

The process of conducting the in-depth interviews followed four steps: 1st Step – Environmentalization/contextualization, introduction, and welcome; 2nd step – Explanation of research intentions and objective, and request for permission to record the interview; 3rd step – Conducting the in-depth interview using an 11-item semi-structured questionnaire; 4th step – Acknowledgments and conclusion.

4.2.3 Data Analysis of study 2

The qualitative analytical procedure consisted of eight steps: 1 – Complete reading of the formatted transcription files (in '*.docx' format); 2 – Classification as described in the section entitled "Research Context and Design"; 3 – Export the 32 files to the Rich Format Text format (*.rtf) so that the Atlas.ti analysis software can import them (Ronzani *et al.*, 2020); 5 – Import the 32 files outlined in step 4; 6 – Continue coding in Atlas.ti, as begun in step 2; 7 – Analysis of categories using Atlas.ti tools, and; 8 – Extraction of analysis reports and encodings.

The analysis process based on coding had a first stage comprised of open coding (Charmaz, 2006). At this stage, it was verified which categories would be useful to achieve the objective that this research proposes, this being done based on the categories initially elaborated in a theory-driven perspective (Saldaña, 2012). Next, axial coding was performed, looking for a cause-and-effect relationship or explanation between the codes and the theory raised. Also in this same process, selective coding took place, which comprises an evaluation of the categories based on a hierarchy in order to determine a level of abstraction that better explains theoretical findings.

Based on theory-driven and data-driven categories in a constant comparison process was applied. As prescribed by Boeije (2002), we proceeded with the constant comparison process following the following relations: comparison within a single interview; comparison between interviews within the same group; comparison of interviews from different groups; comparison in pairs at the level of the couple; comparing couples.

The data-driven categories emerged from the coding process and gained strength as they became a response standard. The search for saturation in the analysis process was based on theoretical sampling, that is, the objective in this type of analysis is not the number of respondents (Charmaz, 2006). Theoretical saturation is obtained by the behaviour pattern of the data, which can be understood by the frequency that a response is given, from a stimulus sent during the interview (Saunders *et al*., 2018).

4.3 Results presentation of Study-2

The findings of the 32 interviews conducted allow us to characterise the interviewees, as presented in the methodology section, and to demonstrate how these results support the notion that distributed cognition enhances collaborative problem-solving within the context of projects, as presented in this section.

4.3.1 Cognitive Style of Leadership

Cognitive style of leadership identified in the sample was holistic, reflective, convergent, and field dependent. As an example of this, the PM-28 said: “Because as you matured the way people understood about projects, we also started to do portfolio management, program management, understand lens criteria and then the prioritization of projects.”. In terms of the reflective style, one of the notable speeches the PM-04 said: “... from the moment the team feels that it can communicate a problem, that it will be dealt with, that it will be important for the project manager, I believe it generates proximity and these problems end up coming from a way in advance, I believe it creates this rhythm of arriving while the problem is still at an easier level to solve.”.

The convergent cognitive style also was demonstrated in speeches such as the PM-11: "So I believe that the first point with the team, is to understand if the team understood what they are doing, is to guarantee that there was an understanding of what is to be delivered, this is my first approach. Second, always respectfully focus on how we're going to solve the problem, because focusing on who's to blame for what, that's not going to get you anywhere.".

In terms of field dependence and independence, the sample presents the field dependence style, as in the case of PM-01 that said: "So, I usually talk to my team, you know, that if you add a variable to chaos, you only increase chaos, you don't decrease it… So, I really seek to give autonomy to the teams to work, and I serve much more as a strategy… who can help the teams to get out of a trap of a problem situation, instead of necessarily defining where they are going to put their hand on what they are going to do.”.

4.3.2 Integrative Learning

The sample allows for the identification of three learning styles, accommodation, assimilation, and convergence. It should be emphasised that these data represent the sample of project managers who were interviewed for the purpose of this study, and that other samples of project managers, or even team-members, may produce different results. In this sample, the assimilator cognitive style was predominant among men, whereas the convergent cognitive style was predominant among women. From the entire sample, the assimilator was the most prevalent, followed by the convergent and accommodator almost tied.

As an example, it is significant to present some of the respondents' speeches. About the accommodating learning style: The PM-28 said: "Give them empowerment to decide like that,

you know, I see that today leaders still have a command-and-control posture, you know? And I think that this humility of the leader of verifying if they can make their own decisions, I say that this came with greater clarity in the coronavirus pandemic, because in the pandemic we had to make absurd efforts...". About the convergent learning style: PM-01 said: "I like to get my hands dirty and learn by doing.". PM-30 said: Because it allows me to check the costumers' maturity, what is best for them. With the hybrid methodology, we get the best of both worlds and calibrate how much of each one will fit in that context, you know?".

Lastly, about the assimilative cognitive style: The PM-14 evidenced: "So, in this communication plan, established at the beginning of the project, I create a link between the engineering of my project, with the engineering of the other project, and so they talk and that's where you can gain knowledge...".

4.3.3 Stakeholder Relationship and Tension

The examined respondents exhibited pertinent indications of tension in project relationships, the PM-23 evidenced about communication with stakeholders that "…a noise in communication can be in the content or it can be in the way you are communicating...", and adds that correct communication process mitigates tension because "... Engagement also obviously depends on communication, the way you communicate...", and generates engagement: "Trust comes naturally, I think when you have transparent communication, right? Trust, it is something that is very difficult for you to conquer. You really need to have an attitude and it's no use talking or wanting to sell an image...".

Regarding daily interactions, the speeches place significant emphasis on the conflicts that arise when interacting with the different types of stakeholders. About this, PM-28 said: "The organization is a set of egos, right? So, you must be able to understand who the person is, ... we report the project in a different way because there are different interests, right? So, for us, it is important to look at the types of stakeholders involved.".

The findings from interviews allow to verify the different groups that comprise the class of stakeholders. Below are the classes of stakeholders, as understood by the interviewees:

Classes of stakeholders:

- Internal classes: CEO (chief executive officer); CFO (chief financial officer); Engineering; Controller; Operations; Finance; Legal; Compliance; LGPD; Marketing; Quality; Sales; Procurement; Security; EHS (environment, health, and safety); Project Team: Team-members, Product Owner, Technical Lead, Designer, Technicians.
- External classes: Regulatory Body: CETESB, Federal Police, ANVISA, Fire Department; Neighbourhood Association; Government Customer: Final Customer, Sponsor, Customer Project Manager.
- External/Internal classes: Private Customer: Final Customer, Sponsor, Project Manager; Suppliers; Shareholders; Management Board.

According to the respondents, the stakeholders' relationship and tension is evidenced by the factors of Tension, Communication, trust building, and Engagement. Starting with Tension, according to respondents, the perception of stakeholders is based on their mental models, and from this point forward, conflict and tension relationships can be mitigated through an honest, flexible, transparent, and resilient posture of project manager, which also takes perception and commitment in win-win relationships into consideration. Interviewees frequently emphasised that a competent project manager must effectively manage the stakeholders' expectations and anxieties, which includes being a good listener to both positive and negative feedback. In general, but relevantly, in relations with stakeholders, the project manager must demonstrate that they do their best for the project, even when problems arise – of the most diverse types – and that he takes an active approach by anticipating and reporting adverse events.

Perception plays a role in the composition of tension and conflict, according to the respondents. About this PM-04 said: "… because I think I have the facility to convince them that I am the person most interested in that project..., they need to believe that the person who is representing, the supplier, the person responsible for the project is really doing the best for them.". Another observation from direct speech relates to the emotional foundations of human relationships. About this PM-11 said: "Talking about emotion is talking about human nature, so I don't see it as good or bad, I see it as a fact and how I'm going to deal with this fact. So, it is important to understand that people have different cognitive and emotional processing speed, but it is also important to bring everyone to the same understanding, that is, to bring people to the rationality of delivery.".

The factor of communication is referenced by the entire sample. According to them, communication alone is insufficient; effective communication is directed at each stakeholder class, capable of mitigating tension and its conflicts, and capable of trust building. According to the respondents, directed communication takes into consideration relevant elements such as planning frequent and adequate information communication – aimed at each stakeholder class. The project manager's integrity, adaptability, transparency, and resiliency, already mentioned in the previous factor, can only be realised through directed communication. An important point raised by the interviewees is that the communication process must reassure stakeholders that the project manager is taking good care of them by managing expectations and anticipating potential negative events, as well as, for some classes, being willing to act as mentors/counsellors.

According to the interviewees' arguments, the project manager should always initiate the process of establishing trust. The project manager words must be congruent with his actions, as evidenced by his ethical, proactive, and transparent attitudes and behaviours, and he must always lead by example. In the tension factor, it was mentioned that the project managers must demonstrate that them are doing their best for the project, and in the communication factor, it was emphasised that the project managers must reassure the project's stakeholders that their needs are being met. All of this has the effect of convincing the stakeholder (continuously) that the involved project manager is the best project manager. The sample also illustrates that previous project experience, the capacity for autonomy and empowerment, as well as feedback management, mentoring, and change management, are predictors of trust and precursors to engagement.

The interviewees mention the engagement factor as a consequence of consistent trust building that is supported by tailored communication. The respondents highlight the importance of understanding the true intentions of each stakeholder, as well as the management of expectations and individuality/personality factors, as core elements of engagement. As with establishing trust building, engagement necessitates attracting postures and interactions directed at each stakeholder class – which vary throughout the project's lifecycle – as well as the continuously conviction that the project manager in question is the best project manager. In addition to the central factors addressed, which include the need for the project manager to be open to offering management by proximity, open to the benefits of co-creation, and if always willing, with the mindset of taking the first step for the relationships, making use of the resources of resilient behaviour, fundamental and repetitive issues resurface in the Engagement

factor. These include posture flexibility, honesty, ethics, and empathy. In this context, previous project experience and social interaction contribute to the Engagement factor. The PM-20 said: "...managing each stakeholder in a different way and another thing I always evaluate is their culture, because the decision-making power and interest they have varies, you know?... trust, it increases engagement and reduces tension because when you trust you disarm yourself.".

4.3.4 Distributed Team Cognition

In the same way that the theoretical framework provides elements that support the proposal of a distributed team cognition model that takes into consideration communication and collective interaction, trust building, collaborative behaviour, and social interaction as potential foundations. PM-21 said about communication: "...as a project manager trying to have the best kind of communication with every level of people...". PM-32 said the collective interaction: "...people need to interact, no one is an island alone, you know? This interactivity... the social interaction of people will promote the construction of this knowledge; this will help the project so that people have the necessary knowledge to be able to make deliveries...". PM-18 said of trust building: "...I think the word transparency just brings trust.". PM-27 said about collaborative behaviour: "Then I believe that when there is collaboration, problems are resolved faster, I have several examples of these in my daily life, examples that worked because of collaboration...". PM-03 said about the social interaction: "...so you left the office, walked a little and you were already in an area that was a club, and this social interaction helped a lot, …it was out of hours, but there was a rapport, which was very good, it was really good.".

The results demonstrate that the directed communication and collective interaction factor was characterised as the most important of the four factors in this section of the model. The interviewees acknowledge that 'day-to-day' communication is the one that makes a difference; it facilitates interaction. Thus, to achieve success in a practical manner, the project manager must understand when it is best suited to approach the team collectively and when the one-over-one approach will be more beneficial. The interviews demonstrate that the one-over-one strategy is more effective when developing a specific or critical point with a team-member.

Communication precedes trust building and is influenced by social interaction. Considering the manager's attitude toward the team, the project manager must be empathetic, flexible, proactive, and respectful, able to offer management based on proximity and psychological safety and valuing bilateral communication and team management expectations. Several interviewees confirmed that in this way, the project managers posture and

the team's expectations have a significant impact on trust building. However, from the project managers are expected to understand that their primary responsibility is to take care of the team that acts on each issue of the project – in essence, empowering and paving the way. Consequently, your message must establish a shared vision of the project for the entire team and emphasise the significance of each member's contribution. This highlights the importance of managing expectations, which reduces emotional conflicts and the likelihood that a team-member will fake results.

The results of the interviews indicate that the project manager conduct is primarily responsible for sustaining the factor of trust building within the project team. First and foremost, the project manager should always initiate relationship-building based on speech and actions that are highly congruent and consistent. In addition to communication, posture, body language, and dress all contribute to trust building. Most respondents emphasise the importance of ethics, seriousness, nature, and individual personality traits in the trust process. The findings indicate that in the project manager capacity as a manager, flexibility is important for win-win relationships with the team, and empowerment influences both the trust process and the construction of knowledge within and between projects.

In general, establishing team trust building also involves cognitive and emotional factors. Consequently, some points of interest emerge from this. In practise, some interviewees mention that assigning a purpose to the team increases trust and interaction, and thus the purpose can have repercussions on how they interact socially; one interviewee warns of the threat that turnover poses throughout this process. After that, some interviewees attributed another point to the psychological security of empowerment. The interviewees reported that it is not sufficient to empower the team; rather, it is necessary to create a psychological safe environment in which individuals can develop and implement their visions in a responsible manner, and potential in the performance of their activities, and therefore, in the occasion of errors and/or failures/mistakes, be confident that they will not be punished for not achieving a particular result – rather, they will be mentored, guided, supported, and protected (in the face of organisation) in order to achieve improved performance. PM-21 said about psychological safety: "When they feel empowered to solve a problem without my needing to hit the hand, because the person has gone down a path that I wouldn't have gone. You see, it's what I said about tolerating the mistake to learn from. I tolerate it because the person made the decision to go down that path, and maybe it wasn't the best decision, but they had a reason why they went down that path. As you undermine attitudes behaviours of people in decision-making, you

reduce their willingness to decide, because the person does not feel comfortable or does not feel empowered to go there and make a decision.".

Based on the findings of the interviews, the collaborative behaviour factor indicates that there must be bilateral resilience between the project manager and the team-members and between the team-members. Relationships must be based on the psychological safety presented in the preceding section, the trust factor – "empowerment alone is insufficient.". Again, interviewees bring up issues regarding which the project manager does not need to be an expert, but is required to understand and care for people, including emotional concerns – the project manager must avoid the expected command and control occasions. In this relationship, the project manager must always be willing to initiate collaboration, in addition to serving as the team's natural shield. In addition to being the spokesperson for the team in front of the organisation, the project manager must manage by proximity, led by example, manage demand in detail (which impacts the level of conflict that can be generated), and always keep the team's objectives clear. Including this, social interaction also contributes, and ultimately, the interviewees call for special attention to human attrition, a result of time and corporate routine interaction.

Some project managers reported using social interaction to make strategic decisions regarding human resources and career development matters. In addition, because the interviewees have participated in national and international projects, they reported that social interaction is able to mitigate cultural and linguistic differences, as well as provide opportunities to increase empathy, communication, and feedback. social interaction also enables the sharing of personal experiences that impact shared knowledge, whereas informal environments exert strong influences on the trust building and team engagement. In general, the social interaction mitigates technical conflicts, but it has the potential to increase behavioural conflicts; therefore, it requires directed communication that is capable of mitigating both types of conflict.

4.3.5 Collaborative Problem-Solving

In this final section, we document the respondents' perspectives on how distributed team cognition improves collaborative problem-solving. Through the perspective of the interviewees, the tension and conflicts factor provide a significant standpoint to understand the collaborative problem-solving. According to the interviewees, the relationship between individuals is the most important factor in explaining the phenomenon, followed by context-environment and then artefacts. The following is a summary of the interviewees' responses:

- Approach to distributed team cognition and analysis of tensions and conflicts:
    - Interpersonal: Formal communication reduces the ability of team-members to deceive and improves interpersonal relationships. Clear and objective communication reduces cognitive dissonance and improves comprehension. Bilateral resilience helps to reduce conflict. When the project manager values the issues raised by team-members, communication is established, and the next issue arises quickly. The project manager should play a conciliatory role in neutrality. Vanity can have an impact on team-members' engagement.
    - Context environment and interpersonal: Divergent interests increase tension and conflict. The decision in context is determined by the level of consciousness of the team-members. Social interaction: reduces interpersonal conflicts and cultural differences, improves communication and feedback, reduces technical conflicts but may aggravate behavioural conflicts.
    - Context environment, interpersonal, and artefacts: Consider challenges as opportunities. Manage customer and team expectations.

As with the factor of tension and conflicts, the factor of team Engagement and the development of human relationships are manifested primarily through individual interactions. The following is a summary of the interviewees' responses:

- Approach to distributed team cognition and analysis of team engagement:
    - Interpersonal: Trust and empowerment support engagement. The consciousness level of team-members influences collaboration. Turnover influences interaction, which in turn affects collaboration. Feeling of companionship and team spirit have an effect on trust. The development of empathy is facilitated by social interaction and communication. The project manager does not need to be an expert in technology, but must be able to manage by proximity, openness,

respect, and example. Ensuring consistency between both actions and words has a positive effect on credibility. Trust is affected by communication, posture, body language, and dress code. The impact of ethics, seriousness, and nature on trust is examined. Trust is affected by the project manager's initiative in relationship building. The 'Win-win' relationship has an effect on trust.

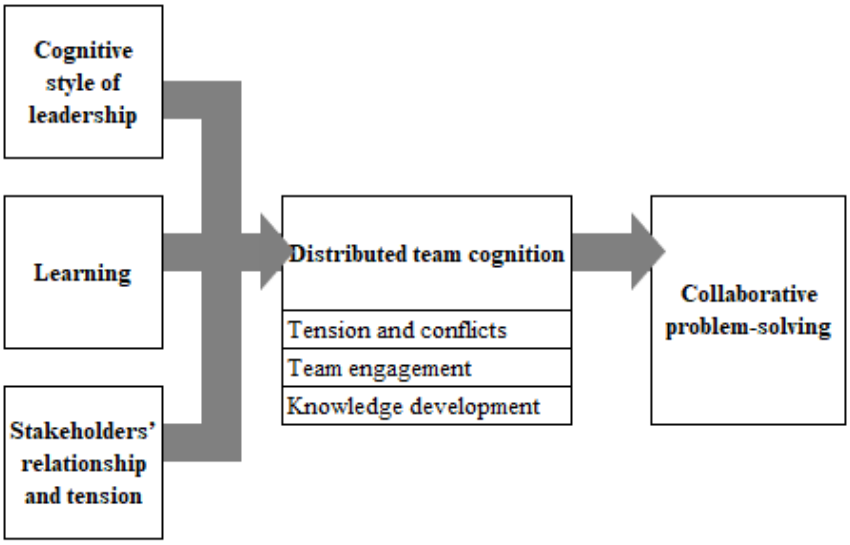
- Context environment and interpersonal: Social interaction, informal circumstances, and connections outside of the workplace enhance trust, interaction, and engagement.
- Context environment, interpersonal, and artefacts: Through communication, creating a common view of project data promotes engagement. Interaction is affected by the balancing and prioritising of information loads over time.

The knowledge development factor continues to pay connected attention to the phenomenon of individual interactions. The following is a summary of the interviewees' responses:

- Interpersonal: Interactions between team-members increase both knowledge and trust. Trust is increased when teammates and the project manager share information. Delegation fosters the growth of collective intelligence. Assisted empowerment promotes the development of knowledge.
- Context environment, interpersonal, and artefacts: Interproject experience increases engagement, trust and promotes the development of knowledge. Social interaction facilitates the exchange of experiences and influences the development of shared knowledge.

Figure 1 shows a model of distributed team cognition based on the factors of tensions and conflicts, team engagement, and knowledge development, as well as the cognitive style of leadership, learning, and stakeholders' relationship and tension as precursors, in order to demonstrate that distributed team cognition enhances collaborative problem-solving capacity.

Figure 1. Proposal for an experimental model elucidating the mechanisms underlying distributed team cognition.



Source(s). Elaborated by the author, 2023.

Respondents provided detailed points on the topic of knowledge management, which facilitates the development of new skills and abilities. PM-13 said: ... knowledge comes with time... the main source of knowledge is my peers and day-to-day colleagues... I have formal knowledge, but for me informal knowledge is the more relevant...". PM-05 said: "...the knowledge is constantly updated... in the social, it interferes with knowledge, communication and interaction...". PM-30 said: "It is at this moment knowledge of the business and not just knowledge of project management processes. Business knowledge makes all the difference because we need to speak the customer's language...".

4.4 Discussion of Study-2

The obtained results allow us to present, as shown in Figure 1, an experimental model composed of the following variables: cognitive style of leadership; integrated learning; stakeholders' relationship and tension; distributed team cognition; and collaborative problem-solving. Returning to the cognitive style of leadership, the examined sample generally exhibited the following style: holistic, reflective, convergent, and field dependent. Considering the position of project management, holistic thinking tends to be the most appropriate in terms of management and learning, given that project management is a multidisciplinary field that evolves in both the technological and interpersonal domains (Chronéer and Backlund, 2015). In terms of the reflective style, the complexity of the project environment impacts intuition and

prior knowledge that promotes the tendency towards the reflective style (Edkins e*t al.*, 2007; Elbanna, 2015).

The convergent cognitive style, on the other hand, can be explained by the tendency to seek a solution to a problem, which involves the synthesis of information through analytical and deductive reasoning, with pre-established rules, a focus on reality, and a dependence on previously acquired knowledge and skills (Colman, 2015). In terms of field dependence and independence, field dependence can indicate that an individual is more intuitive than one who is field independent (Asch and Witkin, 1948).

Cognitive skills and emotional complexity of the project manager can be directly related to leadership capacity and achievement of results (Floris and Cuganesan, 2019), which also take into consideration complex environments, contexts of pressure and uncertainty (Gallagher *et al.*, 2015). Given that the cognitive style of leadership is a prerequisite for the distributed team cognition, a project manager who is holistic, reflective, and convergent can contribute in terms of his leadership capacity in key factors that facilitate collaboration in problem-solving. The expected result of the combination of these three factors – based on the previously cited literature – will be a profile that addresses the project as a whole, without distractions, focusing on caring for the project team that will build the delivery of results, integrating the different areas and factors that relate to the project (holistic), which takes into consideration the complexity of the environment and the use of previous knowledge (reflective), in addition to the management of the project. According to Cuneo *et al*. (2018), depending on the context, one cognitive style may be more suited than the other in terms of field dependence or independence.

Regarding integrated learning, individuals acquire knowledge according to their own preferences. Cognitive intelligence plays an important role in this study because it is directly related to a person's intellectual ability, when relating situations, tasks, contexts, places, and times to a person's learning style. Hatami (2013) postulates when relating situations, tasks, contexts, places, and time with the learning style of the human being. In this study, the term integrated learning was considered because it adheres to the proposal of this experimental study, as integrated learning considers the direct connection between conceptual and experiential learning, which can extend beyond the individual, thereby achieving collective learning, capable of providing more than just information, by forming and/or improving skills, necessary

for unanticipated and/or complex events, pertinent to the context of projects (Leadbeatter, 2021).

In this way, the accommodating learning style (active-concrete), within the context of projects, contributes to the understanding that managers with this style will present a greater tendency towards multiplicity and the execution of real problems, with a preference for teamwork, they deal well with the dynamics of the relationship of obtaining resources to achieve results, maximising opportunities, as well as dealing well with taking risks and the need to adapt to differing circumstances (Seel, 2012). In turn, the convergent style (active-abstract) tends to seek a practical application of ideas in the context of problem-solving – they seek the ideal path – they prefer well-defined tasks and learn better through trial and error, and they value resolution and decision-making.

Both styles identified in the sample have active experimentation as their predominant skill, with the only difference being that the accommodating sample is more susceptible to concrete conceptualization – "what if?" / "what if?" – while the convergent sample is more susceptible to abstract thinking – "how?" / "how?" (Seel, 2012). Lastly, the assimilative cognitive style (abstract-reflective) tends to be organised and logical, with integrated thinking and proficiency in conceptualization, creation of theoretical models, and explicit problem-definition; they benefit from time for reflection and decision-making. They are adept at decision-making and relating cultures and experiences to problem-solving and strategic planning – their guiding question is "why? " (Seel, 2012).

In addition to the cognitive style of leadership and integrated learning, stakeholders make a substantial contribution in the development of the proposed model. Since conflict and tension management is the primary factor that affects stakeholder relationships in projects, the stakeholder concept is associated with tension. According to Moura and Teixeira (2010), everyday interactions between individuals, groups of individuals, and individuals and organisations can result in conflict. Not every stakeholder is strategic for the company and for a given project – that can vary over time and according to the project –, however the project manager is responsible for managing their integration and participation. This is due to the fact that that each class of stakeholder and participant has different interpretations and professional interests (Jenkin *et al*., 2019; Kahvandi *et al*., 2018).

The effectiveness of the emotional management of those involved – which includes individuality/personality factors – can reduce tension; therefore, social interaction can be a

strategic management tool capable of minimising human/emotional factors. Burstrom and Wilson (2018) indicates that tension has both cognitive and emotional components, and Angelucci *et al.* (2023) explain that tension manifests itself in different ways, such as intertwining, competition and superseding. Cuganesan and Floris (2020) discuss the capacity to integrate based on the mental models of project managers, who may feel powerless. Consequently, Habouba-Belinky and Parush (2020) associate feedback with human performance. In this context, Wang *et al*. (2021) emphasise the impact of emotional communication on the ability to collaborate at work. Finally, Floris and Cuganesan (2019) demonstrate that cognitive and emotional complexity impact leadership ability.

Proceeding with the communication factor, the Findings of the study by Drury-Grogan (2021) demonstrate that communication improves the relationship between the individual and the collective. In this sense, Wang *et al*. (2021) demonstrate that emotional factors present in interpersonal communication are directly related to the capacity for team integration. Vaux and Kirk (2018), in previous research, indicated that communication competence in addition to trust building is significant for both problem-solving and enhancing motivation and morale in relationships.

Effective tension management and communication are the basis for the trust building factor. According to Hartman (2003) there are three aspects of trust: 1 – Intuitive trust; 2 – Trust in integrity; and 3 – Confidence in competence must be supported from the beginning of the project by the project manager's empathic communication. In this way, Flavian *et al*. (2019) add empathy to perceived justice and trust antecedents in the manager. Regarding the issue of trust between stakeholders. Takahashi and Takahashi (2022) posit that knowledge sharing necessarily requires the trust building, which is influenced by socialisation and communication, which strengthen the shared vision.

In concluding the engagement factor, Liu *et al*. (2022) demonstrate that informal interpersonal relationships contribute to task performance, thus also enhancing engagement and knowledge construction. Sharpe *et al*. (2021) once considering stakeholder engagement, proposed inclusion criteria that vary according to the project and stakeholder groups, with the goal of enhancing the efficacy of decision-making. These inclusion criteria are level of interest, level of influence, magnitude of impact, probability of impact, temporal urgency/immediacy, proximity, economic interest, rights, justice, and underrepresented/underserved populations. In other words, one of the strongest predictors of project success is the manager's attitude. Cooperative negotiation, according to Yu and Luo (2022), is an interactive approach that

supports the collaborative problem-solving in a higher value construction, in which stakeholders express and understand each other's positions and expectations, and thus seek win-win outcomes.

As previously discussed, distributed cognition influences the success of projects because team performance is directly influenced by the capacity to solve problems collectively. The findings of the interviews contribute to the understanding and application of the concept that distributed cognition occurs through the interaction between individuals, tools, artefacts, and society, as revealed by Hutchins (1995; 2000) and Rogers (1997). In summary, the theoretical review section corroborated and justified the selection of the initial structure, according to Figure 1. Based on extracts from the interviewees' speeches, it is now possible to comprehend how these four factors are interrelated and how distributed team cognition is proposed to be explained.

Still regarding the Communication factor, team performance requires the development of a common mental model of the team-members, consolidated by communication and even influenced by experience (Han and Hovav, 2016). The capacity to reason and solve problems necessitates that the team is adaptable, has a high level of communication, and can resolve conflict (Detzen *et al*., 2018). In addition to enhancing motivation and morale in relationships, communication probably benefits relationships from the individual to the collective (Drury-Grogan, 2021), in addition to improving relationship motivation and morale (Vaux and Kirk, 2018). Lastly, communication competence facilitates feedback, which has the capacity to increase the team's understanding and thereby influence task execution performance (Dwivedula and Bredillet, 2010; Habouba-Belinky and Parush, 2020), in which there is a direct relationship between cognition, task complexity and the team's shared mental model (Lim, 2022).

Regarding the trust building, Julsrud (2008) established that it consists of both cognitive and affective components. In this context, the affective component of the project team, in addition to the resilience capacity of the project team-members, mediates the cognitive component (Pavez *et al*., 2021). According to Mubarak *et al*. (2021) there is a direct relationship between ethical management and team integration and empowerment based on social learning. The study by Flavian *et al*. (2019) linked empathy and perceived justice in the manager as antecedents to trust building, and trust, in turn, is an antecedent to team engagement.

Continuing with the collaborative behaviour factor, Poirier *et al*. (2017) affirm that human cognition in a collaborative environment is influenced by factors resulting from team-

members' expectations, intentions, and incentives. Thereby, an individual's collaborative behaviour is a summary not only of cognitive factors, but also of personality factors (Ajayi *et al*., 2016). When considering proximity management, the project manager must include collaborative behaviour as one of the project management pillars, including prioritising collaborative planning, which engages and improves shared perception (Schultz, Gretsch, and Kock, 2021), and reduces cognitive distancing (Sangwan *et al*., 2020). The extent to which shared cognition is present has a significant influence on enhancing the process that drives a team towards achieving high performance (Byrne and Eddy, 2023).

The social interaction factor facilitates the formation, development, and maintenance of human relationships based on collective interaction, as well as the trust building, and consolidation of collaborative behaviour based on collaborative problem-solving. In this context, the level of team-members' awareness is crucially significant. Social interaction permits a balance between personality and professionalism and provides the project manager with opportunities to identify differences between team-members and assistance in identifying and addressing emotional intelligence issues.

Extending with the social interaction factor, the social interaction influences the behaviour of the team-members during the execution of the project and the construction of knowledge through the use of exchanges in informal relationships, which are correlated with the commitment and involvement of the team-members in the execution of tasks (Liu *et al*., 2022). Social interaction increases relationship interaction through communication (Drury-Grogan, 2021), and the individual's behaviour influenced by social and cultural norms influences performance and conflict management (Loch, 2017). As discussed by several interviewees, trust is one of the antecedents to the level of collaboration that leads to project success. The level of collaboration is directly impacted not only by trust, but also by the balance between the individual differences of the team-members, the social relationships they build, and the incentives they receive; consequently, both engagement and management have significant effect (Bond-Barnard *et al*., 2018).

Finally, according to the speeches of the interviewees, the project manager is a facilitator of resilience. Thus, Pavez *et al*. (2021) explains that in the project environment, resilience is influenced by interpersonal trust and can be defined as the ability to anticipate, contain, and recover from adversity and failures that arise from the uncertain and complex project environment and its contexts.

In this final section, we discuss the respondents' perspectives on how distributed team cognition improves collaborative problem-solving. In the macro perspective, according to them the collaborative problem-solving occurs within the project team and within the context of technology projects as a result of the following three factors: (i) Tension and conflict; (ii) Team engagement; (iii) Knowledge development. Hutchins (1995, 2000) explain that the phenomenon of distributed team cognition is explained by the interactions that result between individuals (interpersonal), the artefacts they use, and the work environment, which is also represented by context (environmental context).

This factor's major contribution is the realisation that engagement must be established on psychological safety. Thus, it is not sufficient to empower the team; it is also necessary to create a psychological safe environment, in which people, in a responsible manner, feel safe to develop, and apply their vision and potential in the performance of their activities, and thus, if they occur errors and/or failures, be assured that they will not be punished for not achieving a certain result – rather, they will be mentored, guided, supported, and protected by both the project manager and the organisation, in order to be successful in another attempt. Moreover, maintaining engagement requires an emphasis on human wear and tear, a consequence of the interaction between time and corporate routine.

According to Anshari and Hamdan (2022), knowledge management facilitates the development of new skills and abilities among team-members. Furthermore, knowledge management can be viewed as a means for the survival of organisations, promoting change through competitive advantages that support innovation. Similarly, Emiliano de Souza *et al*. (2022) explain that knowledge management consists of tacit knowledge tacit knowledge and explicit knowledge. Consequently, explicit knowledge relates more to project management effectiveness and team impact, whereas tacit knowledge relates more to business impact.

Finally, while collaboration for problem-solving is strategic, each individual has a problem-solving style that influences shared understanding and problem-solving performance (Sangwan *et al*., 2020). Findings of the same research emphasise that one of the important functions of the project manager is to properly manage the team's diversity of styles and care for cognitive differences.

4.5 Conclusion and final considerations of Study-2

This study aimed to verify how distributed cognition enhances collaborative problem-solving in the context of project management. The research question that guided the study was: How does distributed cognition enhances problem-solving in a project environment? Consequently, the objective was to evaluate a model of distributed cognition for collaborative problem-solving within the context of projects. For this purpose, a qualitative study was conducted using in-depth interviews with a sample of 32 project managers with national and international experience and familiarity with both traditional and agile methodologies. The analysis process, utilising coding techniques, involved stages: open, axial, coding, and selective coding. These stages encompassed the evaluation of categories based on a hierarchy, in order to determine an appropriate level of abstraction that properly explains theoretical findings.

Based on the project management literature, it was possible to propose a theoretical structure, which served as the basis for the research and provided support for the entire development of the research protocol as well as guiding the development of the interview phase research in depth. To achieve the results, the discussion focused on the concepts of distributed team cognition, which consider the cognitive style of leadership, stakeholders' relationship and tension, and integrated learning for collaborative problem-solving. Conflict and Tension, Team Engagement, and Knowledge Development were identified as the three most important factors for collaborative problem-solving. As an illustration, the Conflict and Tension factor relates relevant communication points that enhance comprehension, resilience, conscientious decision-making, and social interaction. The concept of Team Engagement connects the concepts of empowerment, collaboration based on conscientiousness, engaging communication, posture and performance expected from the project manager, and social interaction. In conclusion, the Knowledge Development factor enhances the efficiency of interactions between individuals, which can transcend organisational boundaries, correlations with deletion and empowerment, and social interaction.

In the remaining section, an exhaustive analysis of the distributed team cognition, which is responsible for enhancing the collaborative problem-solving, was conducted, and different analyses were assigned to the elements that, according to the interviewees, represent the distributed team cognition, namely directed communication and collective interaction, trust building, and collaborative behaviour, as well as its correlation with social interaction and knowledge building. Finally, an extra section made some practical recommendations for project

managers to apply. This research advances in the direction of understand how aspects of distributed team cognition can impact the behaviours of the project professional and contribute to problem-solving in the project environment, applicable both in the academic field, and in public and private organizations.

5. STUDY-3: A DISTRIBUTED TEAM COGNITION MODEL FOR PROBLEM-SOLVING IN PROJECT MANAGEMENT

The Study-3 advances the Study-1 model and the evidence obtained in the Study-2. Study-1 contributed to the understanding of distributed team cognition theory. In Study-2, it was possible to assess how distributed team cognition occurs in the context of a project. In Study-3, the premise is that by assessing the elements of distributed team cognition, it is possible to conclude that distributed team cognition enhances the collaborative problem-solving capacity of project teams.

The importance of problem-solving within project management is widely recognised, regardless of the specific methodology employed (Drury-Grogan, 2021; Ribeiro *et al.*, 2021). The process of problem-solving involves the systematic application of methods and tools to address and resolve problems, independently of whether they are of a known or unknown nature (Barrett, 2018). Collaborative problem-solving is identified as a behavioural aspect that has an impact on both professional performance and individual well-being (Zheng *et al.*, 2020). Problem-solving refers to a highly significant skill in the context of the 21st century. This skill encompasses various components, including: (i) comprehending the essence of the problem; (ii) delineating the stages involved in resolving the problem; (iii) selecting the most optimal strategy for resolution; (iv) specifying the sources of data and compiling a comprehensive list of information required for resolution; and (v) monitoring the successful resolution of the problem (Aslan, 2021).

Findings emerged concerning the augmentation of collaborative problem-solving is enhanced by distributed team cognition. The study revealed that distributed team cognition is affected by the influence of environmental factors, contextual elements, and social interactions. This study examines the enhancement of collaborative problem-solving by the distributed team cognition, which involves team-oriented communication strategies that utilise both collective and individual messages. These communication methods seek to encourage collective interaction among team-members. The study further explores the influence of collective interaction on the trust building within the team, and how team-members subsequently affects collaborative behaviour (Fernandes *et al.*, 2023).

The presence of interdisciplinarity is essential for addressing complex problem-solving and has a significant influence on cognitive coordination (Reijula *et al.*, 2023). Moreover, it is worth noting that conventional approaches to resolving complex problems tend to be ineffective

in the short and medium term, while also promoting methodological conservatism. The role of the project manager and team-members in relation to cognitive intelligence and project success-oriented cognitive skills can be represented by analytical skills, organisational skills, critical thinking skills, and creative skills (Agarwal *et al.,* 2023). Considering these elements and the complex issues of megaprojects, all of this reinforce that a project manager career development is also influenced by the environment and the problem-solving capacity skill (Marrewijk *et al.*, 2023).

Implementing effective management strategies is relevant for promoting the development of problem-solving skills in a collaborative manner. The presence of collaborative problem-solving within the project environment and its various contexts is widely recognised as a crucial element that significantly enhances performance in the problem-solving process and the successful delivery of outcomes (Yu and Lou, 2022). The management and conduct of projects benefit from having a collaborative problem-solving oriented behaviour because it improves the detection of issues and their underlying causes, encourages team-members to contribute their best solutions, and maximises project planning and execution (Hong *et al.*, 2020). When an individual chooses to act independently, they may encounter more challenges in determining the appropriate approach for resolving a situation. On the other hand, collaborative action tends to yield better outcomes due to the synergistic effect of collective understanding and joint efforts (Newton *et al.*, 2018; Hong *et al.*, 2020).

The management of a team following the collaborative problem-solving approach presents relevant benefits, such as improved task organisation, integration of diverse perspectives, experiences, and sources of knowledge, and the generation of creative outcomes through collective performance (Hou *et al.*, 2021). Hence, collaborative problem-solving influences and is influenced by trust building, team communication and collaborative behaviour, which is further potentialized by the presence of psychological safety. Given the involvement of all relevant stakeholders throughout the appropriate project phases, it remains crucial to consider the concept collaborative problem-solving as it plays a significant role in the anticipation of risks, identification of opportunities, and potential changes.

Given the importance of continuing research on how the meaning of collaborative problem-solving can be enhanced by distributed team cognition (Graesser *et al.,* 2018), through engaged and collaborative action relationships between project manager and team-members (Hagermann and Kluge, 2017). The purpose of this study is to examine the relationship between

distributed team cognition and collaborative problem-solving capacity, and thus examine the possible effect of the meaning that individuals attribute to the completion of their tasks within the context of projects.

This research was conducted using a quantitative method to investigate relationship between collaborative problem-solving and distributed team cognition. For this purpose, a questionnaire containing 58 items derived from validated scales and already in use, with 417 respondents, focusing on the following constructs: trust building, team communication, psychological safety, knowledge sharing behaviour, distributed team cognition, and collaborative problem-solving was applied.

This research reveals the importance and relevance of understanding the relationship between collaborative problem-solving and distributed team cognition, exploring some limitations perceived by this study, and indicates the need for future studies in the area of project management. This study has theoretical and practical contributions. This study represents an important contribution to theory by investigating collaborative problem-solving in project management. This research study contributes to the understanding of collaborative problem-solving and distributed team cognition elements and presents practical implications and recommendations for project managers. The result of the study is useful for several stakeholders, project managers and team-members regardless of the organization's segment. The applications of this study are extensible through further adaptations in academic and organizational environments and their contexts.

5.1 Theory background and hypothesis development of Study-3

The trust building supports the individual in becoming confident and at comfortable when sharing their thoughts, ideas, and concerns, without fear of the discomfort of judgement or negative consequences. In other words, it refers to the extent to which an individual is willing to become vulnerable in the face of the actions of others, considering the expectation that the other will perform an action regardless of their ability to control or monitor (Christina *et al*., 2020). According to Hartman (2003), the foundation of trust building is the effective management of tensions and communication, which is comprised of three main elements: intuitive trust, trust in integrity, and confidence trust. According to Ghazinejad *et al.* (2018), open and sufficient communication has a direct impact on team communication, influencing attitudes such as openness, commitment, and trust, which are supported by shared visions and experiences, which are sufficient for collaborative problem-solving. According to Drury-

Grogan (2021), communication improves individual and collective relationships. Therefore, we propose the following hypothesis:

Hypothesis 1 (H1). Trust building is positively related to team communication.

Trust Building requires the development of a sense of dependence, trustworthiness, and beliefs. When an individual trusts another one, he feels safe to be vulnerable and will therefore take risks to behave and express himself without fear of negative consequences, thereby promoting Psychological Safety. When trust is low, psychological safety is impacted, reducing open communication, collaboration, and innovation (Edmondson, 1999; Frazier and Fainshmidt, 2012). The findings by Clark (2020) postulates a four-stage model of psychological safety: safe to be included, safe to learn, safe to contribute, and safe to challenge what is known. Highly effective project teams include collaboration and knowledge sharing behaviour, along with team empowerment through psychological safety and trust building development, and a commitment to shared outcomes (Ahiaga-Dagbui, 2020). Therefore, we propose the following hypothesis:

Hypothesis 2 (H2). Trust building is positively related to psychological safety.

The psychological safety describes an individual's perceptions of the potential outcomes and consequences of interpersonal risks to which he is exposed (Xu and Suntrayuth, 2022), and team communication supported by trust building, when occurring in an open and intended manner, strengthens team communication and collaborative problem-solving (Ghazinejad *et al.*, 2018). Both psychological safety and team communication influence knowledge sharing behaviour, with psychological safety positively influencing individual behaviour that influences knowledge sharing behaviour (Xu and Suntrayuth, 2022) and knowledge sharing behaviour promoting team communication that generates new knowledge, achievements, and innovation (Xu and Suntrayuth, 2022). Studies like that Swart *et al.* 2022 identified that collaboration is the most studied topic in recent research, followed by trust, training, communication, and psychological safety, in that order. Therefore, we propose the following hypothesis:

Hypothesis 3 (H3). Team communication is positively related to knowledge sharing behaviour.

The psychological safety of the team-members and the knowledge sharing behaviour mediate the relationship between entrepreneurial leadership and team creativity (Mehmood, 2022). Trust building between team-members can be defined as a confidence that other team-

members are capable of reproducible work, with shared results and the understanding that results can be considered (Brasier, 2023). In this sense, the relationship between team-members in a context of trust building improves psychological safety, which does not even refer to the fact that the environment is safe enough to take risks and contribute opposing viewpoints. Lastly, and complementary to trust building, cohesion includes elements that act on the team-members to maintain their engagement to the outcomes. Therefore, we propose the following hypothesis:

Hypothesis 4 (H4). Psychological safety is positively related to knowledge sharing behaviour.

Based on the premise that collaborative problem-solving can be enhanced by distributed team cognition and influenced by knowledge sharing behaviour, it is posited that distributed team cognition acts as an effective driver for enhancing the efficacy of collaborative problem-solving (Hagermann and Kluge, 2017; Graesser *et al.,* 2018). In this sense, there is a correlation between the cognitive factor and the knowledge sharing behaviour with elements that explain that informal relationships and interdependence among tasks and team-members serve as significant factors in enhancing relationships and facilitating knowledge exchange (Kangning *et al.*, 2022). Complementary, the interaction between team-members in terms of psychological safety, competitiveness, and knowledge sharing behaviour has an impact on the exchange of experiences and consequently restricts the development of shared cognition thus consolidating the relationship between the sense of psychological safety, knowledge sharing behaviour, and distributed team cognition (Xiau *et al.*, 2022).

The greater the sense of psychological safety among team-members, this can lead to potentialize of knowledge sharing behaviour, resulting in improved organisational status, and enhanced interpersonal relationships. On the contrary, a diminished sense of psychological safety may lead to the suppression of knowledge sharing behaviour, and the cognition of the knowledge sharing behaviour is influenced by the perception of the level of competition (Xiau *et al.*, 2022). Knowledge sharing behaviour aligns with the concept of promoting distributed knowledge and cultivating shared common cognition. However, achieving this objective requires enhancing individuals' comprehension of their own behaviours, intentions, and the cognitive processes of others.

Aligned with the collaborative problem-solving aims, the drive for understanding distributed team cognition increases as we seek to understand the problem-solving to complex

problems, which invariably require team-members to engage in complex collaborative processes (Newton *et al.*, 2018). Cognition is a complex phenomenon that has evolved over time; it refers to the brain processes of mental action, committed to the acquisition of knowledge and understanding by means of thought, experience, and sensory stimuli, and is related to input, storage, and how the stored/learned information is subsequently used to guide human behaviour (Cambridge Cognition, 2015). Cognition is generally responsible for controlling thought and behaviour. Metacognition, on the other hand, applies to learning in a completely conscious manner "learning how to learn" (Colman, 2018).

Metacognition encompasses knowledge and beliefs about one's own cognitive processes, where an individual's objective knowledge about memory processes is an important factor in cognition, as it is related to the level of difficulty in completing a given task, taking into consideration the most appropriate resolution strategies (Colman, 2018). In other words, metacognition refers to awareness of one's own cognitive processes and the ability to consciously control and monitor these individuals (Newton *et al.*, 2018). At this point, metacognition is significantly positive for increasing distributed team cognition and learning in complex contexts, with distributed team cognition dedicated to explaining what results from interactions between individuals, the artefacts they use, and the environment (Hutchins, 1995, 2000). Therefore, we propose the following hypothesis:

Hypothesis 5 (H5). There is a positive effect between knowledge sharing behaviour and collaborative problem-solving that is mediated by distributed team cognition.

The competence of collaborative problem-solving relates to an individual's capacity to actively participate in a process of problem-solving by means of shared understanding and collaborative efforts, guided by individual skills and proficiencies. This necessitates a methodical approach to framing the issue at hand and employing focused facilitation, particularly during the initial phases. Additionally, it involves assuming responsibility and placing emphasis on collaboration (Bertel *et al.,* 2022). Thus, the production and sharing of knowledge can promote collaboration and engagement through the exchange of previous problem-solving experiences and the exchange of new ideas, factors that enhance learning and, in turn, increase collaborative problem-solving performance (Hong *et al.*, 2020).

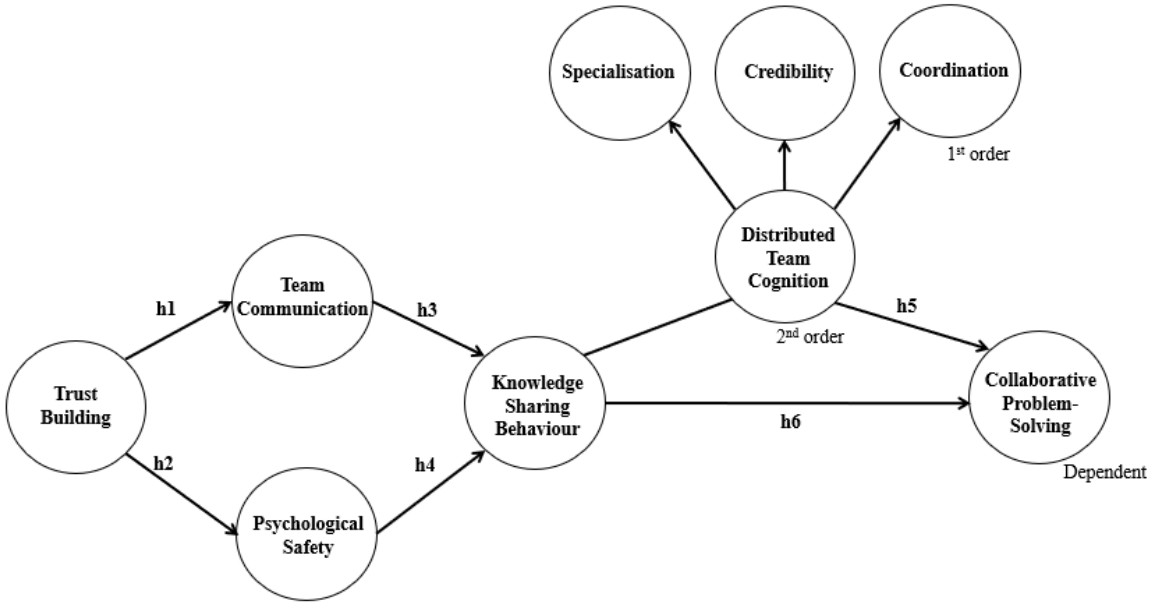
The knowledge sharing behaviour is essential for innovative problem-solving in technology companies; thus, the knowledge sharing behaviour is responsible for contributing to enhanced performance. In this context, it is important to dedicate attention to how knowledge

sharing behaviour occurs so that there is a balance between knowledge sharing behaviour and the competitive behaviour necessary to assure the knowledge sharing behaviour (Hong *et al.*, 2022). Leadership and trust building have influence so that there is an appropriate knowledge sharing behaviour. In this sense, the leadership style (transformational or authoritative) defines outcomes. Transformational leadership is linked to both implicit and explicit knowledge sharing behaviour, whereas authoritarian leadership is only linked to explicit knowledge. Trust building, on the other hand, influences collaborative behaviour, which in turn influences knowledge sharing behaviour, and is influenced by individual behaviour, individual cognition (which considers the perception of one's own behaviour and the behaviour of other team-members), and the environment (which carries their contexts) (Jiang and Chen, 2021). Therefore, we propose the following hypothesis:

Hypothesis 6 (H6). Knowledge sharing behaviour is positively related to collaborative problem-solving.

The conceptual model with the hypotheses is presented in Figure 1.

Figure 1. Research model.



Source(s): Elaborated by the author, 2023.

This model presents both constructs and hypotheses. It starts out with knowledge sharing behaviour, which is influenced by team communication, psychological safety, and trust building. Additionally, there is a second-order variable referred to distributed team cognition, which is formed by specialisation, credibility, and coordination, which enhances collaborative problem-solving, as proposed in this study. The next section presents the methodology of this research.

5.2 Materials and methods of Study-3

5.2.1 Participants

The definition of sample size adhered to the guidelines indicated by Hair *et al* (2019), which suggest a minimum of five responders per question. The present study consists of a total of 58 questions, with a sample size of 417 respondents, resulting in an average of 7.19 respondents per item. The software G*Power 3.1 was employed in a sequential manner to determine the required number of replies for the study, as described by Ringle *et al.* (2014). In accordance with the instructions provided by Hair *et al* (2019), the number of predictors was set at two, the effect size was set to be 15%, a probability of error was set at 5%, and the statistical power was chosen to be 80%. The findings revealed a significant critical F value of 1.68, with a minimum sample size of 43 valid responses. This analysis was conducted using the

following statistical procedures: t-tests for the 'test family' and linear multiple regression with fixed model, single regression coefficient for the 'statistical test', and the 'type of the power employed was an 'a priori' analysis, compute required sample size – given α, power, and effect size.

The sample has 417 respondents, with 355 respondents (85.1%) being Brazilians and 62 respondents (14.9%) being non-Brazilians. The sample consists of individuals with different non-Brazilian nationalities. More specifically, there are 11 Germans (2.6%), 7 Americans from the USA (1.7%), 6 Indians (1.4%), 5 Swiss (1.2%), 4 Italians (1.0%), 4 Mexicans (1.0%), 3 English from the UK (0.7%), 3 Egyptians (0.7%), 2 Argentines (0.5%), 2 Chileans (0.5%), 2 Spanish (0.5%), and 13 individuals from other nationalities, each contributing 0.2% individually and collectively corresponding to 3.1% of the total sample. These other nationalities include Denmark, Ghana, Italy, Pakistan, Portugal, Romania, Sudan, Sweden, Syria, Togo, Turkey, Ukraine, and Venezuela.

Upon querying the participant regarding their self-identification as either a PM or a TM, the resulting proportions were determined to be 65.5% for PMs and 34.5% for TMs. Regarding experience, the structure that aligns with that used in the Pulse of Profession report by the (Project Management Institute, 2023). This structure categorises experiences into five distinct ranges. The data obtained from the sample, considering the five categories is presented in Table 1. Among the collected data, it is observed that 70.3% of the sample falls into the range of values between 1 and 2.

Table 1. Years of experience of respondents in the sample.

Range	Experience level	Respondents	Subtotal
1	Over 20 years	140	33.6%
2	From 10 to 19 years	153	36.7%
3	From 5 to 9 years	66	15.8%
4	From 2 to 4 years	36	8.6%
5	Up 2 years	22	5.3%
	Total	**417**	**100%**

Source(s): Elaborated by the author, 2023.

One of the demographic questions was about the approach employed in the respondent's most recent project, which was taken into consideration during the completion of the survey. The data collected revealed that out of the total sample, 79 participants (18.9%) reported utilising an agile methodology, 112 participants (26.9%) reported utilising a traditional

methodology, and 226 participants (54.2%) employed a hybrid methodology. The size of the respondents' company was also taken into consideration, adopting the categorization provided by Eurostat (2023) in the database published on the official website of the European Union. The corresponding information is displayed in Table 2.

Table 2. Company size of the respondent.

Company size of the respondent	Respondents	Subtotal
More than 250 employees	272	65.2%
From 50 to 249 employees	70	16.8%
From 10 to 49 employees	39	9.4%
Up to 10 employees	36	8.6%
Total	**417**	**100%**

Source(s): Elaborated by the author, 2023.

In the present investigation, a total of 417 individuals participated as respondents. Among them, 163 respondents (39.1%) identified as females, 252 respondents (60.4%) identified as males, and 2 respondents (0.5%) chose not to reveal their gender. Table 3 provides information regarding the age distribution among the participants, while Table 4 presents data on their level of education.

Table 3. Age range of the respondent.

Range	Age range of respondent	Respondents	Subtotal
1	From 20 to 29 years old	64	15.3%
2	From 30 to 39 years old	137	32.9%
3	From 40 to 49 years old	138	33.1%
4	From 50 to 59 years old	58	13.9%
5	From 60 to 69 years old	17	4.1%
6	Over 70 years	3	0.7%
	Total	**417**	**100%**

Source(s): Elaborated by the author, 2023.

According to Table 3, 79.9% of the 417 respondents fall inside ranges 2 to 4. The maximum concentration of the 163 females is in ranges 2 and 3, which represents 66.9% of the total (and 76.7% between ranges 2 and 4). Of the 252 males, 65.1% fall inside ranges 2 and 3, and 81.7% fall inside ranges 2 to 4. Data is also consistent with experience, as 61.3% of the 163 female respondents have over 10 years of experience, while 75.8% of the male sample (considering the 252 male respondents) have over 10 years of experience.

Table 4. Education of the respondent.

Education of respondent	Respondents	Subtotal
Post-Doctoral degree	4	1.0%
Doctoral degree	19	4.6%
Master's degree	68	16.3%
Postgraduate diploma	219	52.5%
University or bachelor’s degree	90	21.6%
Certification programs diploma	17	4.1%
Total	**417**	**100%**

Source(s): Elaborated by the author, 2023.

The data presented in tables 1 to 4 provide a comprehensive description and assessment of the sample employed in this research.

5.2.2 Procedure

The selected sample comprises solely project managers and team-members. The selection criteria were established by exclusively examining recognised professionals who are presently working in projects or who have been appropriately recommended based on their career. To achieve this objective, an electronic form was applied. The form was made available in two languages, Portuguese, and English, using the Google Forms service. It was accessible throughout the period from June to August 2023. Prior to providing their responses, participants were initially introduced to the survey and only after agreeing to participate did they proceed to answer the available questions. Upon completion of the data collection process, all replies were then included into a database for the purpose of conducting analysis.

5.2.3 Instruments and variables operationalisation

A two-part research instrument was utilised for the purpose of this investigation. The first part presented demographic questions, and the second section was dedicated to questions about the study variables. This study's variables were measured using a research instrument that comprised items from six validated and previously applied research scales. Each selected scale represents a construct from which the hypotheses are derived, and which comprises the research objective. Table 5 presents the study constructs, scales authors, scale additional information and item example.

Table 5. Study constructs, scales authors, information, and item example.

Study Constructs	Scale Author	Scale Information	Item example
Team communication	Lochner (2020)	The team communication can be measured with a questionnaire covering 'communication & teamwork' that consists of 9-item questionnaire to measure 1 dimension	"I prefer to stay quiet when other people in a group express opinion that I don't agree with. (R)." "I feel comfortable working in a group"
Team psychological Safety	Edmondson (1999)	The psychological safety can be measured with a questionnaire covering 'psychological safety' that consists of 7-item questionnaire to measure 1 dimension	"Members of this team are able to bring up problems and tough issues." "It is safe to take a risk on this team."
Trust building	Yamagishi *et al*. (2015)	The trust building can be measured with a questionnaire covering trust' that consists of 9-item questionnaire to measure 1 dimension	"Generally, I trust others." "I hate to lose because of having counted on someone. (R)"
Knowledge sharing behaviour	Hooff *et al*. (2003)	The knowledge sharing behaviour can be measured with a questionnaire covering 'knowledge sharing' that consists of 7-item questionnaire to measure 1 dimension	"I ask other members of this team what they know when I need particular knowledge." "The other members of this team tell me what they know, when I ask them about it."
Distributed team cognition	Heavey and Simsek (2014)	The distributed team cognition can be measured with a 15-item questionnaire to assess the 3 dimensions of distributed team cognition through the 'transactive memory systems items', namely: 'Coordination', 'credibility', and 'specialization', with 5 items per dimension	"When other team members give information, I tend to double-check it for myself. (R)." "Our team works together in a well-coordinated fashion."
Collaborative problem-solving	Sanatkar and Rubin (2023)	The collaborative problem-solving scale can be measured using a questionnaire to assess the 'problem-solving style scale', with a 10-item to measure 2 dimensions, observing the preference for solving problems in a 'dependent' or 'independent' manner, with 5 items each	"I do not like to depend on other people to help me to solve my problems." "I prefer to consult with others before making important decisions. (R)"

Source(s): Elaborated by the author, 2023.

For the purpose of this research, we only sought to use scales already established in other studies, and that were by renowned authors, with relevant findings, as is the case with researcher Emm's psychological safety scale. It was used a 7-Likert scale for all study variables (1 = Strongly Disagree, 7 = Strongly Agree). This research includes the full instrument in its supplementary materials.

5.2.4 Data analysis

The data collected using Google Forms was exported in the '.csv' format and afterwards incorporated into the SmartPLS4 software programme. This software was utilised for conducting descriptive analyses as part of the present study. Furthermore, a series of basic mediation analyses were conducted to examine the impact of collaborative problem-solving. The methodology employed by Hayes (2018) was utilised for this objective, and the examination was iterated for each of the independent variables and dimensions of the conceptual model. In all instances, the examination of the relationships between variables included an analysis of both direct and indirect effects. Additionally, the bootstrapping approach was employed, with a confidence interval of 95%, to further investigate these effects. This research did not use any control variables.

Mediation is checked to determine whether it is complete or partial. However, as Hayes (2018) pointed out to the size of the indirect effect found. Many statistical indicators have been proposed in recent years as appropriate for informing on the size of the mediation effect, although there is still no clear consensus (Hayes, 2018; Lachowicz *et al.*, 2018). In this study, the completely standardized value of the indirect effect is referred to, which allows us to compare the weight of the indirect effect of each of the predictor variables in each model Hayes (2018). Moreover, the proportion mediated is included, which indicates what percentage of the total effect is due to mediation.

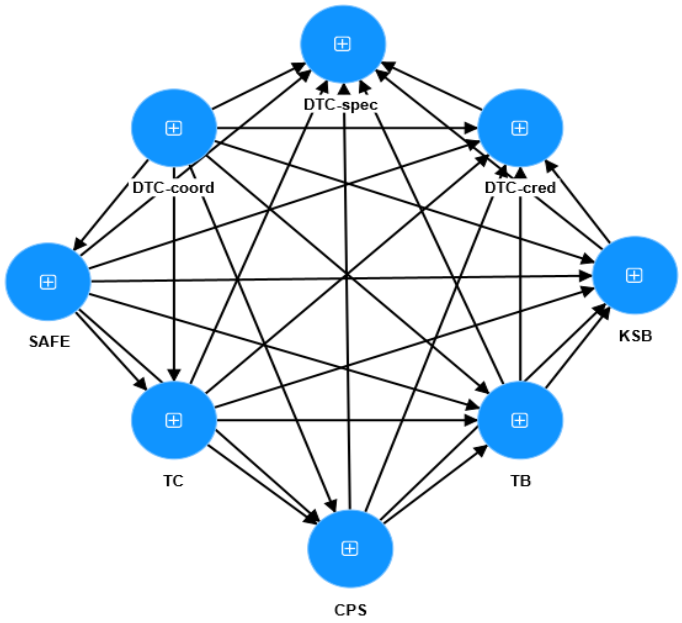
5.3 Results of Study-3

To simplify reading, the variables analysed in this section will use equivalent acronyms, namely: TB – Trust building; SAFE – Psychological safety; TC – Team communication; KSB – Knowledge sharing behaviour; DTC – Distributed team cognition, and CPS – Collaborative problem-solving. The database is described in the materials and methods section, encompassing a total of 417 qualified respondents belonging from the domain of project management. The collected database was subjected to analysis using the SmartPLS4 programme, employing various steps of analysis. The researchers employed the Partial Least Squares Structural Equation Modelling (PLS-SEM) approach to develop the model. All tests were conducted in accordance with the PLS-SEM method computation, with the Path – Standardised – Default setup and a weighting vector of none. Based on the analyses conducted, several observable variables were identified with load values that were below the suggested limit of 0.7. In the present context, indicators characterised by a significant margin of error and minimal loadings

were excluded from the model (Byrne, 2001; Hair *et al.*, 2014). In accordance with the previous recommendation, the selection of observable variables was conducted in a parsimonious manner, prioritising those with the lowest loading on each latent variable. This approach also followed to the guideline that the least acceptable value for average variance extracted (AVE) should be 0.50, as proposed by Hair *et al.* (2019).

The analysis of the empirical model and the research model will be described below, starting with the empirical model, as illustrated in Figure 2.

Figure 2. Empirical model.



Source(s): Elaborated by the author, and extracted from the SmartPLS4, 2023.
Note: PLS-SEM model.

The analysis initiates with convergent validity before proceeding to discriminant validity. In the reliability analysis, it is assumed that the construct is unidimensional, i.e., that its convergent validity and discriminant validity are adequate. Therefore, if there is a problem with convergent or discriminant validity, the reliability evaluation cannot continue (Bido and Silva, 2019). Table 6 illustrates the composite validity (rho_c) and the average variance extracted (AVE) for the empirical model, considering the sequential elimination of factor loadings that were below 0.7.

Table 6. Quality criteria – construct reliability and validity for the empirical model.

	Composite reliability (rho_c)	Average variance extracted (AVE)
CPS	0.770	0.631
DTC-coord	0.691	0.466
DTC-cred	0.894	0.635
DTC-spec	0.742	0.593
KSB	0.840	0.640
SAFE	0.876	0.779
TB	0.761	0.528
TC	0.880	0.596

Source(s): Elaborated by the author, and extracted from the SmartPLS4, 2023.

Note: Calculate menu: PLS-SEM algorithm – Path – Standardized – Default – Weighting vector none. Reporting menu: Quality criteria – Construct reliability and validity.

Henseler *et al.* (2016) demonstrated that the identification of inadequate validity is most effectively accomplished by employing the 'Heterotrait–Monotrait ratio' indicator (HTMT). The study by Gold *et al.* (2001) also proposes a threshold value of 0.90. Discriminant validity for the empirical model is presented in Table 7.

Table 7. Discriminant validity – Heterotrait-monotrait ratio (HTMT) – Matrix for the empirical model.

	CPS	DTC-coord	DTC-cred	DTC-spec	KSB	SAFE	TB	TC
CPS								
DTC-coord	0.469							
DTC-cred	0.742	0.634						
DTC-spec	0.151	0.627	0.131					
KSB	0.824	0.58	0.904	0.243				
SAFE	0.625	0.604	0.908	0.138	0.807			
TB	0.795	0.565	0.864	0.215	0.821	0.907		
TC	0.823	0.551	0.878	0.151	0.872	0.892	0.942	

Source(s): Elaborated by the authors, and extracted from the SmartPLS4, 2023.

Note: Calculate menu: PLS-SEM algorithm – Path – Standardized – Default – Weighting vector none. Reporting menu: Quality criteria – Discriminant validity.

The rho_c and AVE indicators were utilised to assess if the sample is reliable. The rho_c value must be greater than 0.7 (Hair *et al.*, 2009). Table 8 presents the discriminant validity of Fornell-Larcker criterion for the empirical model.

Table 8. Discriminant validity – Fornell-Larcker criterion for the empirical model.

	CPS	**DTC-coord**	**DTC-cred**	**DTC-spec**	**KSB**	**SAFE**	**TB**	**TC**
CPS	**0.794**							
DTC-coord	0.311	**0.683**						
DTC-cred	0.476	0.617	**0.797**					
DTC-spec	-0.007	0.150	0.049	**0.7**70				
KSB	0.501	0.476	0.758	0.019	**0.800**			
SAFE	0.394	0.557	0.710	-0.043	0.630	**0.882**		
TB	0.456	0.414	0.653	0.008	0.611	0.599	**0.726**	
TC	0.538	0.483	0.758	-0.073	0.737	0.696	0.689	**0.772**

Source(s): Elaborated by the author, and extracted from the SmartPLS4, 2023.

Note: Calculate menu: PLS-SEM algorithm – Path – Standardized – Default – Weighting vector none. Reporting menu: Quality criteria – Discriminant validity.

Considering the values placed diagonally in Table 8 are related to the square root of the AVE and are bigger than the correlations between the latent variables, the discriminant validity was validated (Bido and Silva, 2019). Table 9 presents the cross loadings for the empirical model.

Table 9. Discriminant validity – Cross loadings for the empirical model.

	CPS	DTC-coord	DTC-cred	DTC-spec	KSB	SAFE	TB	TC
CPS-02.interd	0.672	0.091	0.287	0.007	0.328	0.124	0.247	0.268
CPS-07.indep	0.900	0.349	0.448	-0.013	0.456	0.438	0.445	0.539
DTC-01.spec	0.018	0.155	0.042	0.857	-0.012	-0.036	0.004	-0.058
DTC-03.cred	0.240	0.221	0.514	0.019	0.366	0.358	0.362	0.370
DTC-05.spec	-0.039	0.063	0.034	0.672	0.053	-0.031	0.010	-0.056
DTC-06.coord	-0.109	0.280	-0.010	0.341	-0.110	0.016	-0.098	-0.182
DTC-09.cred	0.420	0.444	0.806	-0.051	0.679	0.577	0.543	0.660
DTC-12.coord	0.172	0.708	0.386	0.205	0.319	0.282	0.243	0.222
DTC-13.cred	0.446	0.600	0.903	0.109	0.677	0.616	0.575	0.682
DTC-14.cred	0.427	0.564	0.910	0.055	0.687	0.646	0.589	0.674
DTC-15.coord	0.288	0.906	0.569	0.110	0.414	0.558	0.381	0.474
DTC-16.cred	0.326	0.545	0.787	0.051	0.547	0.585	0.505	0.577
KSB-02	0.507	0.424	0.751	-0.029	0.904	0.612	0.578	0.748
KSB-03	0.241	0.203	0.351	0.116	0.650	0.218	0.252	0.315
KSB-04	0.395	0.458	0.622	0.014	0.825	0.571	0.550	0.599
TB-01	0.377	0.395	0.548	-0.030	0.501	0.538	0.841	0.607
TB-02	0.156	0.176	0.184	0.056	0.145	0.275	0.475	0.265
TB-04	0.396	0.295	0.575	0.024	0.559	0.452	0.806	0.551
TC-03	0.368	0.347	0.571	-0.103	0.546	0.563	0.537	0.793

TC-05	0.519	0.503	0.771	-0.077	0.741	0.663	0.636	0.851
TC-06	0.396	0.319	0.451	-0.083	0.451	0.481	0.466	0.693
TC-07	0.369	0.348	0.483	-0.011	0.471	0.477	0.497	0.748
TC-08	0.401	0.311	0.585	-0.002	0.581	0.468	0.499	0.765
TPS-02	0.383	0.524	0.617	-0.047	0.549	0.885	0.513	0.626
TPS-06	0.312	0.459	0.636	-0.029	0.563	0.880	0.544	0.602

Source(s): Elaborated by the author, and extracted from the SmartPLS4, 2023.

Note: Calculate menu: PLS-SEM algorithm – Path – Standardized – Default – Weighting vector none. Reporting menu: Quality criteria – Discriminant validity – Cross loadings.

Table 9 indicates that the highlighted factor loadings are greater than the cross loadings, confirming the discriminant validity of the measurement model (Bido and Silva, 2019). Consequently, the empirical model corresponds with the applied sample.

In light of this, once the prerequisite validations have been completed, the research model is presented below. Following the completion of the previous procedure it was determined that certain loads exhibited values below the required threshold of 0.7. These loads, along with their respective values, are as follows: TB-02= 0.532, TC-06= 0.691, KSB-03= 0.65, DTC-06= 0.485, and DTC-05= 0.629. As a result, the decision was made to retain these values based on their proximity to the zone of tolerance. To achieve this objective, it was decided that necessary to evaluate the notion that indicators with external loadings ranging from 0.40 to 0.70 should only be eliminated from the scale if their exclusion results in an improvement in the composite reliability (rho_c) or the average variance extracted (AVE) that exceeds the recommended threshold value, as defined by Hair *et al.* (2011). In the present line of argumentation, we have considered the possibility of not omitting these indicators. This is because indicators with lower external loadings may still be utilised, considering their contribution to the overall content validity, as suggested by Hair *et al.* (2011).

SmartPLS4 provides an overview of research fit metrics, including Standardised Root Mean Square Residual (SRMR), Squared Euclidean Distance (d_ULS), Geodesic Discrepancy (d_G), Chi-square, and Normed Fit Index (NFI). The SRMR is a widely used measure in the examination of structural equations utilising the Ordinary Least Squares (OLS) technique. The d_ULS and d_G indexes are employed for the purpose of assessing the sufficiency of model fit, with lower values indicating a higher level of model fit. The NFI calculates the Chi-square statistic for the proposed model and compares it to a relevant reference point. Given that the Chi-square value of the proposed model does not offer adequate information for evaluating

model fit, the NFI use the Chi-square value derived from the null model as a benchmark. Table 10 presents the research model, focusing exclusively on the operationalized components.

Table 10. Quality criteria – model fit for the research model.

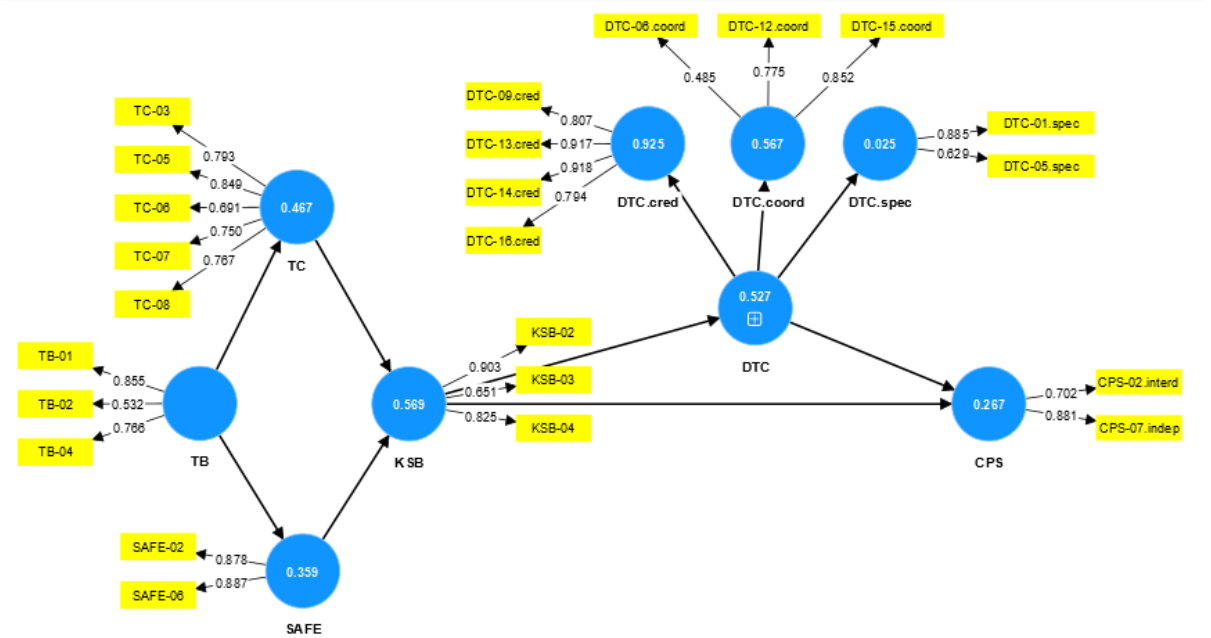
	Saturated model	Estimated model
SRMR	0.137	0.162
d_ULS	11.164	15.553
d_G	n/a	n/a
Chi-square	∞	∞
NFI	n/a	n/a

Source(s): Elaborated by the author, and extracted from the SmartPLS4, 2023.

Note: Calculate menu: PLS-SEM algorithm – Path – Standardized – Default – Weighting vector none. Reporting menu: Quality criteria – model fit.

According to Henseler *et al.* (2014), it is recommended to set limits for the SRMR at a value below 0.10 or at 0.08. According to Lohmöller (1989), it is suggested that the NFI index should be less than 1. Figure 3 shows the items, together with their respective item's loadings, within the circles representing the latent variables. These loadings indicate the R-square value for each construct.

Figure 3. Distribution of final path loadings and indication of R-square for the research model.



Source(s): Elaborated by the author, and extracted from the SmartPLS4, 2023.

Note: Calculate menu: PLS-SEM algorithm – Path – Standardized – Default – Weighting vector none. Reporting menu: Graphical – Graphical output (Outer model: loadings; Constructs: R-square).

The evaluation of construct reliability and validity, as described in the model proposed by Hair *et al.* (2014), is presented in Table 11. The analysis primarily focused on the convergence of the model, specifically examining the extent to which the components exhibit a substantial amount of shared variance (Hair *et al.*, 2014). Hair *et al.* (2016) state that the minimum acceptable value for rho_c is 0.7, with a parsimonious limit of 0.6. The obtained values are within the recommended range.

Table 11. Construct reliability and validity for the research model.

	Cronbach's alpha	Composite reliability (rho_c)	Average variance extracted (AVE)
CPS	0.440	0.774	0.635
KSB	0.725	0.840	0.640
TB	0.565	0.768	0.534
TC	0.830	0.880	0.596
SAFE	0.716	0.876	0.779
DTC	0.770	0.825	0.381
Coord	0.592	0.756	0.521
Cred	0.882	0.919	0.741
Spec	0.324	0.736	0.589

Source(s): Elaborated by the author, and extracted from the SmartPLS4, 2023.

Note: Calculate menu: PLS-SEM algorithm – Path – Standardized – Default – Weighting vector none. Reporting menu: Quality criteria – Construct reliability and validity.

Hair *et al.* (2014) also argues that the values of AVE should above the limit of 0.5. In this particular instance, with the exception of the variable DTC= 0.381, all other variables comply to this condition. The second-order variable, DTC, can be assessed by examining the first-order variables, namely coordination, credibility, and specialisation, to determine if they meet the minimum AVE criteria. The AVE values for coordination, credibility, and specialisation are 0.521, 0.741, and 0.589, respectively. The present phase of the research provides evidence of the model's convergent validity, as supported by previous studies (Byrne, 2016; Hair *et al.*, 2016; Pituch and Stevens, 2015).

After confirming the factor loadings of each variable in the model, it is necessary to evaluate the convergent validity by examining the rho_c indices and corresponding AVE values. According to Hair *et al*. (2014), in exploratory research, Cronbach's alpha values should fall within the range of 0.60 to 0.70 to be considered satisfactory. Therefore, the obtained values are as follows: TB= 0.565, which is in close proximity to the lower limit; CPS= 0.440, maybe attributed to the constraint imposed by the limited number of items; and the two primary

variables of the second-order DTC variable, Coord= 0.592, nearing the lower limit, and Spec= 0.324.

In the same way that the HTMT was verified for the empirical model, Table 12 presents the HTMT for the research model, considering the literature of Henseler *et al.* (2016) and Gold *et al.* (2001).

Table 12. Discriminant validity – Heterotrait-monotrait ratio (HTMT) – Matrix for the research model.

	CPS	**KSB**	**TB**	**TC**	**SAFE**
CPS					
KSB	0.824				
TB	0.795	0.821			
TC	0.823	0.872	0.942		
SAFE	0.625	0.807	0.907	0.892	

Source(s): Elaborated by the author, and extracted from the SmartPLS4, 2023.

Note: Calculate menu: PLS-SEM algorithm – Path – Standardized – Default – Weighting vector none. Reporting menu: Quality criteria – Discriminant validity.

In the same way that the discriminant validity of Fornell-Larcker was validated for the empirical model, Table 13 demonstrates the Fornell-Larcker results for the research model.

Table 13. Discriminant validity – Fornell-Larcker criterion for the research model.

	CPS	**DTC**	**KSB**	**SAFE**	**TB**	**TC**
CPS						
DTC	0.710					
KSB	0.824	0.879				
SAFE	0.625	0.871	0.807			
TB	0.795	0.840	0.821	0.907		
TC	0.823	0.835	0.872	0.892	0.942	

Source(s): Elaborated by the author, and extracted from the SmartPLS4, 2023.

Note: Calculate menu: PLS-SEM algorithm – Path – Standardized – Default – Weighting vector none. Reporting menu: Quality criteria – Discriminant validity.

The collinearity statistics, namely the Variance Inflation Factor (VIF), were examined to evaluate the presence of multicollinearity among the variables in the model. According to Hair *et al*. (2014), the recommended threshold for VIF values is 10, while it is considered optimal to have values below 5, as illustrated in Table 14.

Table 14. Collinearity statistics (VIF) for the research model.

ITEM	VIF	ITEM	VIF	ITEM	VIF
DTC-01.spec	1.039	DTC-13.cred	4.113	KSB-04	1.488
DTC-01.spec	1.221	DTC-14.cred	4.174	TB-01	1.326
DTC-03.cred	1.194	DTC-14.cred	4.301	TB-02	1.132
DTC-05.spec	1.054	DTC-15.coord	1.164	TB-04	1.202
DTC-05.spec	1.039	DTC-15.coord	1.793	TC-03	1.781
DTC-06.coord	1.186	DTC-16.cred	1.745	TC-05	2.025
DTC-06.coord	1.507	DTC-16.cred	2.122	TC-06	1.472
DTC-09.cred	1.864	CPS-02.interd	1.086	TC-07	1.630
DTC-09.cred	1.986	CPS-07.indep	1.086	TC-08	1.715
DTC-12.coord	1.266	KSB-02	1.794	TPS-02	1.451
DTC-12.coord	1.517	KSB-03	1.351	TPS-06	1.451
DTC-13.cred	4.486				

Source(s): Elaborated by the author, and extracted from the SmartPLS4, 2023.

Note: Calculate menu: PLS-SEM algorithm – Path – Standardized – Default – Weighting vector none. Reporting menu: Quality criteria – Collinearity statistics (VIF).

Although several indices being in proximity to the recommended values, it was recognised that the model exhibits a satisfactory level of fit (Kline, 2005, pp.134). There is a potential for a suboptimal fit between some elements of the model and the data, because of the presence of anomalous outcomes that necessitate explanation. This circumstance does not necessarily mean that the model possesses predictive efficacy. Nevertheless, our aim was to prioritise simplicity when adjusting the data (Hair *et al*., 2005). Upon evaluating the R-square coefficients it was observed that the values exceed the threshold of 0.20, as indicated by Hair *et al.* (2014). This indicates a satisfactory level of explanatory power for the model. In the present context, pertaining to the domain of social and behavioural science. Cohen (1988) proposes that an r-square value of 2% should be categorised as a small effect, an r-square value of 13% as a medium effect, and an r-square value of 26% as a large effect. Hence, the values of the model are indicative of a substantial impact. The r-square values are presented in Table 15.

Table 15. R-square overview for the research model.

	R-square	R-square adjusted
CPS	0.267	0.263
DTC	0.527	0.526
KSB	0.569	0.567
SAFE	0.359	0.357
TC	0.467	0.466

Source(s): Elaborated by the author, and extracted from the SmartPLS4, 2023.

Note: Calculate menu: PLS-SEM algorithm – Path – Standardized – Default – Weighting vector none. Reporting menu: Quality criteria – R-square.

The f-square statistic is employed to assess the extent to which each construct contributes to the adjustment of the model. According to Hair *et al.* (2014), values of 0.02, 0.15, and 0.35 are classified as small, medium, and large, respectively. In this way, it was observed that the relations of TB → TC=0.877, TB → SAFE= 0.560, TC → KSB=0.401, and KSB → DTC= 1.116, have large effects, in addition to the relations of SAFE → KSB= 0.063, KSB → CPS= 0.085, DTC → CPS=0.023, can be considered medium effects (Hair *et al.*, 2014). Subsequently, the model's validity was evaluated by examining the initially formulated hypotheses. The outcomes of this evaluation are presented in Table 16.

Table 16. Hypothesis, path coefficients, t-values and R-square for the research model.

		Final results			
Structural relation	**Hypo-thesis**	**Path coeff.**	**T values**	**P values**	**Hypothesis Label**
TB → TC	H1(+)	0.684	23.274	0.000	Supported
TB → SAFE	H2(+)	0.599	16.806	0.000	Supported
TC → KSB	H3(+)	0.577	12.845	0.000	Supported
SAFE → KSB	H4(+)	0.229	4.469	0.000	Supported
KSB → DTC → CPS	H5(+)	0.137	2.878	0.004	Supported
KSB → CPS	H6(+)	0.364	6.103	0.000	Supported

Source(s): Elaborated by the author, and extracted from the SmartPLS4, 2023.

Note: Calculate menu: Bootstrapping – Subsamples: 10000 – Do parallel processing: checked – Complete (slower) – Generate results per sample: checked – Studentized bootstrap – Two tailed – Significance: 0.05 – Random seed – Path – Standardized – Default – Weighting vector none. Reporting menu: Graphic – Graphic output.

According to hypothesis 5, we intended to investigate how much distributed team cognition mediated the relationship between knowledge sharing behaviour and collaborative problem-solving. The mediation effect (indirect effect) was significant, as shown in Table 17.

Thus, the distributed team cognition mediated approximately 27.35% of the relationship between knowledge sharing behaviour and collaborative problem-solving.

Table 17. Hypothesis-5 – mediation verification for the research model.

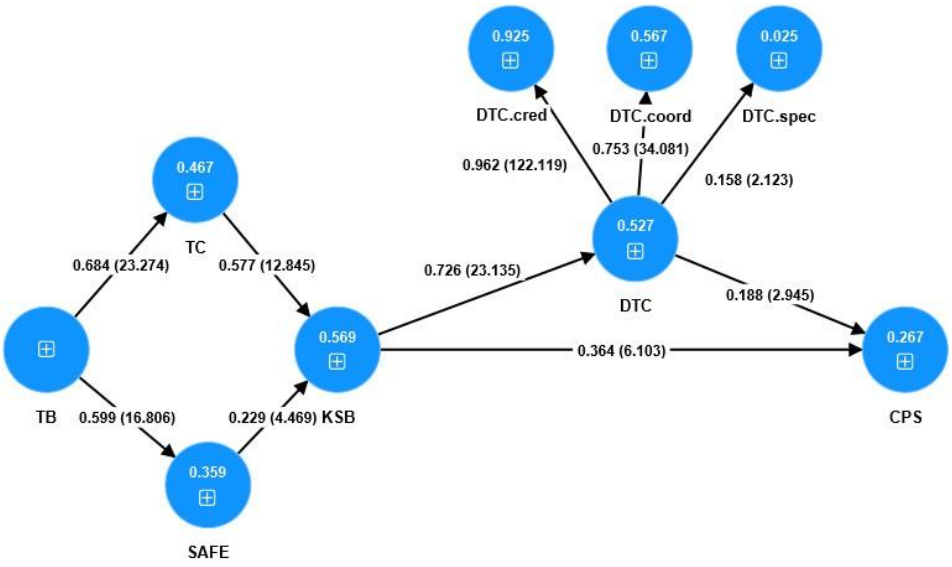
Simple Mediation					
Type of effect	**Effect**	**Path coefficient**	**T stats**	**P value**	**Remarks**
Total effect	KSB -> CPS	0.501	13.267**	0.000	Sig total effect (TE)
Indirect effect	KSB -> DTC -> CPS	0.137	2.878**	0.004	Sig indirect effect (IE)
Direct effect	KSB -> CPS	0.365	6.058**	0.000	Sig direct effect (DE)
VAF	IE / TE	27.35%			
Conclusion	Moderately Partial Mediation Exists				

Source(s): Elaborated by the author, and extracted from the SmartPLS4, 2023.

Note: Calculate menu: Bootstrapping – Subsamples: 10000 – Do parallel processing: checked – Complete (slower) – Generate results per sample: checked – Studentized bootstrap – Two tailed – Significance: 0.05 – Random seed – Path – Standardized – Default – Weighting vector none. Reporting menu: (TE): Final results – Total effects. (IE): Final results – Total indirect effects. (DE): Final results – Path coefficients.

Figure 4 graphically demonstrates the results from table 16. The constructs (inside the blue balls) show the R-square values, and the inner model (between constructs) show the path coefficients and t-values inside the parentheses.

Figure 4. Distribution of path coefficients, t-values and R-square for the research model.

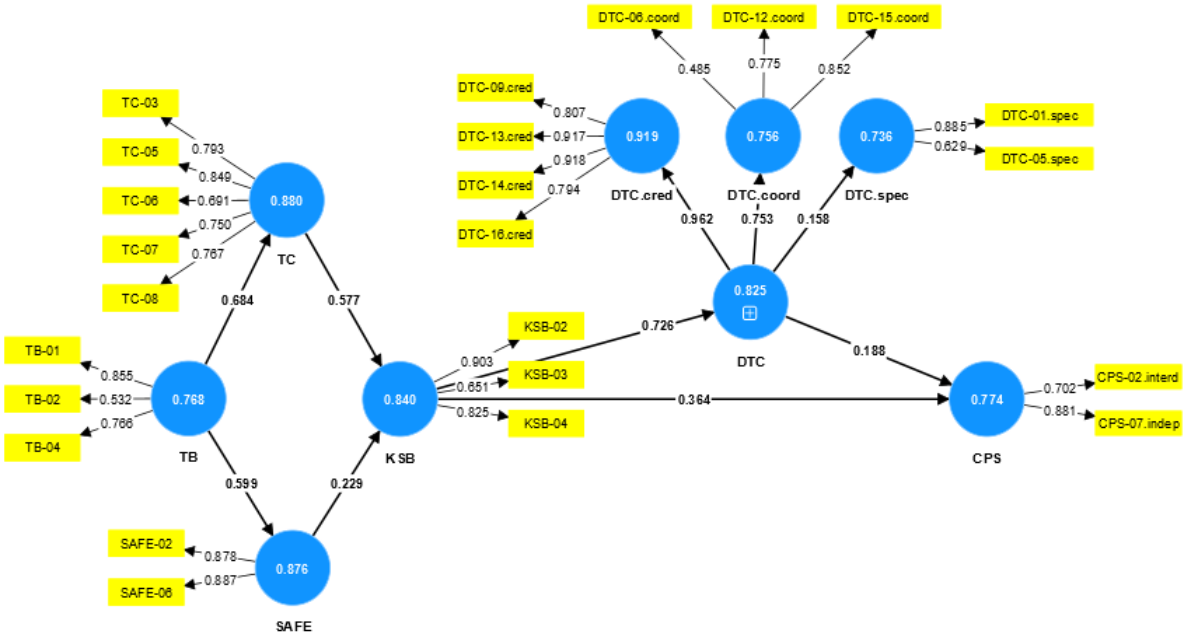


Source(s): Elaborated by the author, and extracted from the SmartPLS4, 2023.

Note: Calculate menu: Bootstrapping – Subsamples: 10000 – Do parallel processing: checked – Complete (slower) – Generate results per sample: checked – Studentized bootstrap – Two tailed – Significance: 0.05 – Random seed – Path – Standardized – Default – Weighting vector none. Reporting menu: Graphic – Graphic output.

In terms of rho_c, and based on the 0.05 significance level, the statistical test must have a modulus greater than 1.96 in order to reject the null hypothesis that the estimated parameter is equal to zero. According to Byrne (2001), parameters that are not significant, save for variances, may be considered unimportant to the model. The observation of path loadings and corresponding rho_c values in Table 16, and Figure 5 provides data for hypothesis H1, H2, H3, H4, H5 and H6.

Figure 5. Distribution of path loadings and indication of composite reliability (rho_c) for the research model.



Source(s): Elaborated by the author, and extracted from the SmartPLS4, 2023.

Note: Calculate menu: PLS-SEM algorithm – Path – Standardized – Default – Weighting vector none. Reporting menu: Graphical – Graphical output (Outer model: loadings; Inner model: path coefficients; Constructs: rho_c).

The subsequent section initiates a discussion and examination of the results that have been offered inside this particular section.

5.4 Discussion of Study-3

The aim of this study was to explore a distributed team cognition model that focuses on collaborative problem-solving within the field of project management. Similar to earlier research developments, they conducted an examination of collaborative problem-solving, considering the cognitive processes of team cognition or distributed team cognition, that include: Wolfert *et al.* (2022) – Differences between remote and analog design thinking through the lens of distributed team cognition; Johnston *et al.* (2019) – A team training field research study: Extending a theory of team development; Zu *et al.* (2019) – Computational simulation of team creativity: The benefit of member flow; Newton *et al.* (2018) – Macrocognition in teams and metacognition: Developing instructional strategies for complex collaborative problem-solving; Wiltshire *et al.* (2018) – Multiscale movement coordination dynamics in collaborative team problem-solving; Wiltshire *et al.* (2017) – Problem-solving phase transitions during team collaboration; Fiore *et al.* (2017) – Collaborative problem-solving and team development: Extending the macrocognition in teams model through considerations of the team life cycle.

According to the findings, the suggested model of this study, despite its limitations, supports the notion that distributed team cognition enhances collaborative problem-solving. Figure 4 illustrates that both the distributed team cognition and knowledge sharing behaviour may explain up to 26.7% of collaborative problem-solving. In this study, team communications and psychological safety can explain up to 56.9% of knowledge sharing behaviour. Our study confirms that there is a positive effect between trust building and team communication, and thus confirms support for hypothesis 1. In agreement with this finding, the study by Sagar *et al.* (2023) demonstrates that team performance is highly affected by trust building which is improved by the quality level of team communication, as well as Drury-Grogan (2021) establishes that the communication process improves relationships at an individual and collective level.

The findings also demonstrated that trust building also has a positive effect with psychological safety, making it possible to confirms support for hypothesis 2. Another relevant fact from this result is that the Cronbach' alpha was possibly lower than recommended since the construct has only two valid items. Despite this limitation, studies such as Edmondson (1999) demonstrate that trust building has a direct impact on psychological safety and team communication, and the findings of Joo *et al.* (2023) indicate that organizational trust, leadership capacity and psychological safety are related to mitigating conflict in the team.

Both team communication and psychological safety, which is based on trust development, have a positive effect with knowledge sharing behaviour. Our findings confirm support for hypothesis 3, which established a positive effect between team communication and knowledge sharing behaviour, as well as found confirms support for hypothesis 4, which established a positive effect between psychological safety and knowledge sharing behaviour. These findings are consistent with previous research that indicated a relevant connection between these constructs. Suk *et al.* (2023), for instance, confirmed a beneficial relationship between management communication style and the team's potential for creativity and knowledge sharing (hypothesis 3). In the same way, Agarwal and Anantatmula (2023) reaffirm the importance of psychological safety as a direct predictor of knowledge sharing behaviour, and Riviera *et al.* (2021) indicate that organisations must pay attention to how management is developed, avoiding abusive management behaviours through the development of skills and abilities, and thus creating an environment with psychological safety capable of enhancing knowledge sharing behaviour (hypothesis 4).

Furthermore, Hypothesis 5 was confirmed by the assessment of the positive effect between knowledge sharing behaviour and distributed team cognition. The study conducted by Kangning *et al.* (2022) found a significant relationship between cognition and knowledge sharing behaviour. Similarly, Xiau *et al.* (2022) demonstrated that in order to promote distributed knowledge through knowledge sharing behaviour, teams must enhance their understanding of their own intentions, behaviours, and cognition. This can be achieved by developing a culture of experiential and practical training. Continuing with the exploration of knowledge sharing behaviour, the results demonstrated a significant effect on collaborative problem-solving, consequently confirming the positive effect of hypothesis 6. The correlation seems to be stronger when factors involve exchanging prior knowledge in order to generate new ideas and create common knowledge (Hong *et al.,* 2020).

By hypotheses 5 and 6 of this research, it was feasible to demonstrate a positive effect between the two main constructs investigated in the study. Distributed team cognition explores the consequences of the interaction among individuals, individuals and artefacts, and the environment (Hutchins, 1995, 2000). The study conducted by Ouyang *et al.* (2022) demonstrates that collaborative problem-solving capacity may be effectively improved by activities that focus on social, behavioural, and cognitive aspects, as well as through effective management. Indeed, the application of distributed team cognition greatly enhances

the team's potential for development by facilitating collaborative problem-solving. Team communication, emotional regulation, and collaboration abilities are crucial factors in problem-solving proficiency (Wang *et al.,* 2021).

Lastly, according to Table 17, the mediation effect (indirect effect) was statistically significant. The mediation test confirmed a proportional effect (PE) of: PE = direct effect / total effect = 0.728, and the distributed team cognition mediated about 27.35% of the relationship between knowledge sharing behaviour and collaborative problem-solving.

5.5 Conclusion and final considerations of Study-3

The aim of this study was to explore a distributed team cognition model that specifically examines collaborative problem-solving in the domain of project management. The study places particular emphasis on validating the actual influence of distributed team cognition in this process. The objective was achieved, and both the findings and the supporting theory framework provided valuable insights and significant points for the field of project management.

In this relationship between distributed team cognition and collaborative problem-solving capacity, the technique for solving problems needs to be developed in order to reach the stage of team engagement, which will become the culture of collaboration, and later, as the team matures of projects, will become a behaviour and a delivery capacity. In fact, there are many different aspects to problems that can be known, anticipated, or unforeseen (Barrett, 2018), and obtaining high efficiency in problem-solving depends on establishing consistent interactions among teammates. At this stage, cognition is applied in its most effective form, emerging from the team's collective intelligence. It influences behaviour, appropriating artifacts and being empowered by the environment and its contexts (Barrett, 2018; Rouleau *et al*., 2021).

In this scenario, the project manager plays a crucial role in orchestrating the management so that project teams are effectively developed with the larger vision of achieving collaborative problem-solving capacity, through the development of individual cognition, and thus, generate individual contributions, within an environment with a sense of psychological safety, continuously fed by directed communication, due to only then will the team feel the autonomy and safety (freedom) required to perform effectively and accomplish its goals.

These findings contribute to the field of project management and may be applied as a tool for project team management. Given the importance of comprehending the implications of

distributed team cognition and how it can improve collaborative problem-solving capacity, relevant elements that emerge and can comprise this tool may include: (i) psychological safety; (ii) direct team communication; (iii) continuous culture learning; (iv) knowledge sharing behaviour; (v) team development and training, and (vi) collaborative decision-making.

6. TECHNICAL-TECHNOLOGICAL PRODUCT (PTT)

The analysis of distributed team cognition elements in human behaviour and their relationship with collaborative problem-solving capacity can be a complex process, given that behavioural research demands collaboration with project research and other areas from psychology research (McNeese *et al.* 2020). Team cognition has significance in determining how a project team should behave in order to achieve performance results and value delivery (Fernandez *et al.* 2017). Hutchins (1995) characterises distributed team cognition as a phenomenon explained by interactions between people, the artefacts they use, and the work environment, which is also represented by context.

Poirier *et al.* (2017) discuss this topic, stating that cognitive factors are important in achieving collaborative behaviour, as well as influencing collective cognition by influencing how information is organised and distributed within the project team, and thus supporting the idea of collective delivery capacity for creativity (Aggarwal and Woolleyb, 2019). As previously discussed in the appropriate section, the human brain possesses both cognitive and behavioural processes. Cognition as an antecedent and behaviour as an output process that occurs after decision-making, that is supported by distributed team cognition theory (Barrett, 2018; Rouleau *et al.*, 2021).

In order to prepare a team with a high capacity for collaboration and the ability to solve problems collaboratively, it is necessary to initiate a strategic process that incorporates individual development and training in order to reach the collective. In this way, collaborative problem-solving capacity manifests itself in a wide range of ways, with elements that consolidate collaboration competence, such as shared comprehension and collaborative efforts guided by individual skills and proficiencies.

To develop a competency in collaborative problem-solving requires a methodical approach to framing the issue at hand, the use of focused facilitation, and an emphasis on responsibility and collaboration (Bertel *et al.*, 2022). Thus, creating and sharing of knowledge is essential, as it promotes collaboration and engagement through the exchange of prior problem-solving experiences and the exchange of new ideas, which enhance learning and, in turn, enhance collaborative problem-solving efficiency (Hong *et al*., 2020).

On the basis of the information presented, it is clear that the understanding of distributed team cognition in behaviour is an opportunity for organisations and professionals to adopt a

management tool that assists in the identification of relevant factors to consider in the continuous, systematic, and experienced development of project team-members. Due to their nature, purpose, and context in which they were developed, traditional methods of assessing human and organisational behaviour can lead to erroneous conclusions, as they fail to take into account the key issues and specifics of project management and human behaviour in projects, which are materialised by the relationship between people, artefacts, context, and society (Hutchings, 1995; 2000).

This research investigation is an applied study aimed at resolving a specific technical and/or scientific problem. In this context, it is noted that a conscientious and critical approach to research procedures and paradigms can generate significant advances in applied knowledge areas (Silva *et al.,* 2018). This research consists of three studies in addition to the publication of a practitioner-oriented bibliography product on a website sponsored and managed by Siemens AG – Germany. This PTT attempts to construct a bridge simply and briefly with the practitioner in order to establish a connection with the practitioner through all of the content developed in this thesis. This interaction with the practitioner occurred within a platform built and funded by Siemens company, as represented for knowledge sharing among internal corporate practitioners and the general public of technology and projects.

The research phases are displayed in Figure 2, which was presented earlier in this document. Figure 3 displays a sample from this publication – in addition, see Annex A.

Figure 3. Publication of the technical-technological product.

Source(s). Elaborate by the **author**, 2023.

Note: Available at https://blog.siemens.com/2023/10/how-does-team-cognition-in-behaviour-enhance-collaborative-problem-solving-in-the-context-of-project-management/

To achieve at the technical-technological product presented here, a number of methodological procedures were utilised that corresponded to the research activities that led to the three studies (refer to Figures 1 and 2). A Systematic Literature Review conducted in Study-1, was guided by the protocol presented by Pollock and Berge (2018), consisting of 4 stages, guided by a research question, and executed for a literature review, critical analysis, discussion of results, and presentation of categories discovered, as well as the proposal of a conceptual model of distributed team cognition. Furthermore, an exploratory field research was conducted in Study-2 using a protocol based on the theory discovered in Study-1 (see Appendix A), with a survey of 32 project managers, a proposal of a model of cognition, and the identification of its supporting elements. The Study-3 utilised a proposed questionnaire based on findings identified by Study-1 and abstracted by the proposed findings of Study-2 (see Appendix B).

Thus, as one of the outcomes of this thesis, a technical-technological product. of type 'Bibliographic Product' was produced, characterised by CAPES as GT 1 – *Qualis Técnico/Tecnológico* (CAPES, 2019). According to the CAPES (2019) technical production guide, this technical-technological product corresponds with a production with a low innovative impact, as it applies the combination of knowledge articulated by the studies in this thesis.

Furthermore, the applicability has a medium impact, as the topic and objective of this research are applicable in both academia and organisations, particularly in the context of projects.

The Bibliographic Product has a high adherence in the Postgraduate Programme in Project Management (PPGP), as the integration of the academic and professional environment in the fields of administration and project management is highly desirable. Moreover, as a publication with a clear purpose of promoting the theme of distributed team cognition applied to collaborative problem-solving in the context of project management, this doctoral thesis makes significant contributions to theoretical and practical fields related to the PPGP proposal. This research aligns with research line 3: "Innovation in Projects" related with the Postgraduate Programme in Project Management – PPGP UNINOVE, as well as other research aligned with the "Behavioural Economics" axis in projects; and as a means of elucidating the evaluation of the research's product, it was evaluated in accordance with Adherence to the programme, Impact, Applicability, Innovation, and Complexity, as shown in Table 1.

Item evaluated	Argumentation
Adherence *(Aderência)*	High – the PTT is directly related to the program's line of work, as well as the research line in project management
Impact *(Impacto)*	High – the PTT will bring benefits in problem-solving and performance in projects, which will allow to reduce errors and delays in solving problems in projects
Applicability *(Aplicabilidade)*	Medium – the PTT can be applied in the context of projects during the phases of the project management life cycle, both in solving problems in the planning phase and in the adversities that arise from project management
Innovation *(Inovação)*	Low – the PTT presents practices and tools for collaborative problem resolution in the context of projects
Complexity *(Complexidade)*	Medium – the PTT presents a high level of complexity as it involves different fields of knowledge and social actors for its elaboration and validation

Table 2. Technical production assessment.

Source(s). Elaborated by the author, 2023.

This technical-technological product, represented by the 'Bibliographic Product', presented a brief framework to the community of practitioners in project management, consolidating in a practical manner the findings from the 3 studies comprising this thesis. Figure 4 illustrates the publication of the brief framework.

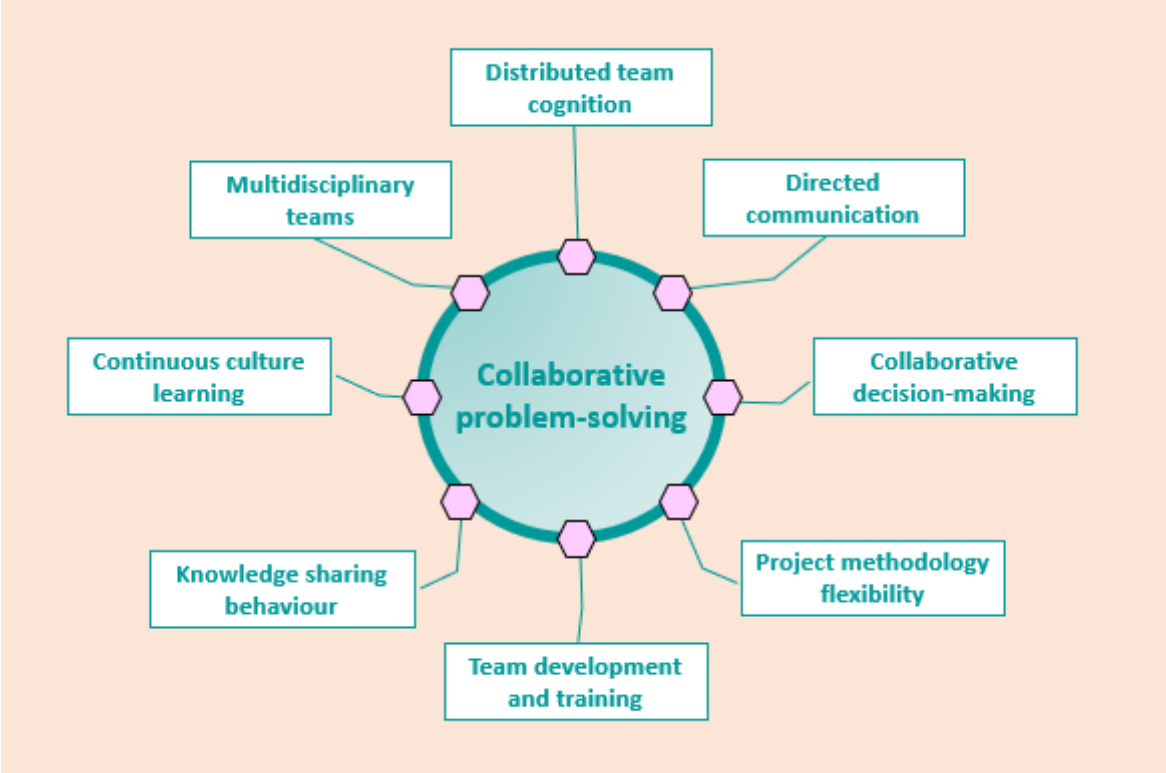


Figure 4. Brief framework according to bibliographic product.

Source(s). Elaborate by the author, 2023.

In this 'Bibliographic Product', a brief framework is presented that considers 8 key elements to be observed, as shown in the preceding figure, as well as providing a practitioner with examples of possibilities and applications and a conclusion that aligns with the understanding of how distributed team cognition provides advantages that enhance collaborative problem-solving.

7. CONCLUSION

Studying team cognition allows us to understand how individual cognition translates into team behaviour dynamics, how team-members interact with their environment, and how they engage with tools, artefacts, and society. These findings apply to both local and remote contexts. The study of team cognition enables the integration and examination of human capabilities, encompassing the interplay between actions and thoughts together with their cognitive states, ultimately shaping human behaviour within organisational project contexts.

Applying appropriate strategies to understand how distributed team cognition influences project management allows managers to do more than just identify behavioural mechanics. It enables the development of new skills models and solutions that anticipate events and, depending on the company's business segment, the implementation of training methodologies to prepare managers and project teams for daily challenges.

The field of project management differentiates out from other areas of study due to its emphasis on multidisciplinary teams and the crucial requirement for collaborative engagement in problem-solving activities to deliver value. The team-members' wide multidisciplinary backgrounds contribute to a comprehensive a range of competencies and expertise for problem-solving. Nevertheless, this range of differences can also pose obstacles to cooperation in different project situations, which is crucial for the achievement of project objectives.

Given the significance of understanding how cognitive factors might impact team-members and contribute in collaborative problem-solving within project circumstances, this study is justified. The proposed distributed team cognition verification provides elements that facilitate the comprehension of collaborative aspects, consequently, it can facilitate in the identification of which of these attributes should be enhanced or refined within the project’s context.

Therefore, in order to answer the research question: How does distributed team cognition enhances problem-solving in a project environment?’, a composition of three interconnected studies was proposed, where the findings of one study provided inputs for the development of the next study. In the study-1, a systematic literature review was conducted to provide a comprehensive overview of how the topic of cognition was being researched and reported, in its current state of the art. This review provided categories of analysis and a conceptual model of distributed team cognition that would offer as the foundation for further

research. The findings of study-1 have been published in the Journal of Management & Technology, which can be accessed at: http://revistagt.fpl.emnuvens.com.br/get/article/view/2646.

In the study-2, an investigation of the state of practise was conducted through field research to examine how practitioners deal with the subject topic. The aim was to compare the theory obtained in study-1 with real-world practise, based on 32 interviews with project managers. The findings of study-2 have been published in the International Journal of Management Projects in Business, which can be accessed at: https://www.emerald.com/insight/content/doi/10.1108/IJMPB-05-2023-0100/full/html.

The study-3, in turn, aimed to contribute to the overall objective by conducting a survey and attempting to understand the relationship between the constructs (latent variables) that were theoretically identified in study-1 and investigated by practitioners in study-2. Therefore, this methodological approach in the three studies allowed us to achieve the overall objective of the thesis, which was manifested in the delivery of a technical-technological product (PTT), described in Section 6 and available online at: https://blog.siemens.com/2023/10/how-does-team-cognition-in-behaviour-enhance-collaborative-problem-solving-in-the-context-of-project-management/ and according to Annex A.

This PTT aims to build a bridge simply and briefly with the practitioner, in order to establish a connection with the practitioner through all the content developed in this thesis. This connection with the practitioner took place within a platform created and sponsored by Siemens company, designed for the sharing of knowledge among internal practitioners of the company and the general public. On November 1, 2023, when searching for information using the phrase 'project management', a notification appeared stating that 50 authors had produced content regarding "project management". The language used by PTT is appropriate for the intended audience of professionals, since it adheres closely to the criteria set forth by the platform and undergoes validation by an administrator before to publishing.

The PTT facilitates comprehension of the distributed team cognition, which offers benefits that enhance collaborative problem-solving capacity. When considering the application of project team management, the following factors must be taken into account: (i) continuous learning, (ii) improved decision-making, and (iii) effective problem-solving. Continuous learning involves the integration of specialised knowledge and experiences to create a collaborative and collective work model. Consolidated by team-members acting

together, collaborating on the project, gaining experience from others in their projects, and using objects and environments that improve both individual and group competencies.

Improved decision-making can be achieved by incorporating a variety of approaches derived from diverse training and competencies, resulting in a wide range of background perspectives and adequate decision-making process. This approach to problem-solving emphasises the use of a concise framework that promotes innovative thinking, the exploration of non-traditional solutions, the cultivation of creativity, and the delivery of value in a flexible manner. As a result, it reduces the time needed to identify and implement effective solutions.

In terms of relevance and significance of the findings for the project management area, the significance of distributed team cognition findings emphasises the collaborative intelligence that emerges from team-member interactions. Furthermore, regardless of physical proximity, and the significance of distributed team cognition enables collaborative problem-solving capacity by taking advantage of the strengths of individual team-members and for the recognition of the interdependence of cognitive processes across the team, demonstrating the need for a supportive and collaborative environment.

This thesis study has an impact on creating a better organisational environment through the resolution of collaborative problem-solving. The findings can extend beyond the organisational domain, since this knowledge is linked to individuals, where it is observed that in more collaborative environments, overall performance increases, even allowing for the development of new competencies. Distributed team cognition brings about an equalisation of knowledge and expertise among the multiple actors involved in each problem-solving process.

As a recommendation for future research, additional studies could be conducted to validate the identified categories and the proposed model. The other suggestion would be to conduct field experiments with project managers, project team-members and stakeholders to validate and improve the proposed cognitive model presented in this thesis. Case studies can be conducted by utilising multiple cases and ensuring adequate sample sizes to accurately represent the phenomenon under investigation.

In order to validate the proposed model and its components, further research should be conducted through qualitative and quantitative studies. These studies could examine how distributed team cognition enhances collaborative problem-solving within project contexts. As an illustration, based on study-2, it is important to conduct the study again with a sample of the

team-members and compare the findings with those from this investigation. Furthermore, it is crucial to replicate this study across several sectors outside from technology, as well as across different cultural and linguistic contexts.

Still with attention to the sample, since this research used a mixed sample, with experience, knowledge, and training in both methodologies, from traditional to agile, it would be relevant to verify whether isolated samples of traditional and agile may show some variation in terms of modelling. Finally, since the approach was to verify whether the distributed team cognition enhances the collaborative problem-solving, it would be advisable and desirable to develop a readiness scale for distributed team cognition, capable of measuring the elements presented in the distributed team cognition category.

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APPENDIX A – INTERVIEW PROTOCOL OF STUDY-2

A. Initial data: from the researchers

i. Researcher: Roberto Godoy Fernandes, doctoral student
ii. Advising professor: DR Leonardo Vils
iii. Co-advisor Professor: DR Luciano Ferreira da Silva

B. Interview conditions:

i. Sample of respondents:
   a. Sample type: Project managers.
   b. Sample selection: selected for convenience.
   c. Experience: National and/or international, and used to both project methods, from traditional to agile.

ii. Interview: additional information
   a. Collection period: from July to August 2022.
   b. Place: via Google Meet, with audio, video, and automatic speech transcription.
   c. Interview duration: scheduled for 45 minutes each one.

C. Instructions for respondents:

You were selected for this interview because you have experience in project management. Our area of study is project-related human behaviour. I would want to emphasize that your participation is entirely voluntary and extremely valuable to our research. If requested, results will be provided later. To facilitate in the analysis of the interview's content, it will be recorded; however, the recording of the interview may be interrupted at any time. Only researchers involved in the process will have access to this recording, and the identities and companies mentioned will never be made public. The transcription of the interview, together with the recording, can be requested immediately following the interview, or at any time thereafter.

D. Analysis category:

Analysis Category	Category Description	Reference Authors	Question	Observation Unit
Cognitive Style of Leadership	This category considers PM's cognitive style theory, as there are differences in how people perceive, think, make judgments, and make decisions. Thus, this category observes the presence of the cognitive style in terms of holistic/serialist, impulsive/reflexive, divergent/convergent and dependent field/independent field	Asch and Witkin (1948) Weissenberg and Gruenfeld (1966) Green (2004) Hanna *et al* (2016) Cuneo *et al*. (2018)	Q1	Holistic or serialist behaviour
			Q2	Impulsive or reflexive thinking
				Divergent or convergent thinking
			Q3	Dependent field style or independent field style
Stakeholders' Relationship and Tension	This category aims to observe the relationship of stakeholders in projects, considering the key issues of communication, engagement, trust building and tension management	Collinge and Harty (2014) Lu and Yan (2016) Burstrom and Wilson (2018) Kahvandi *et al*. (2018) Jenkin *et al*. (2019) Sperry and Jetter (2019) Cuganesan and Floris (2020) Qian *et al*. (2020) Guo *et al*. (2021)	Q4	Presence or absent to communication, engagement, trust building and tension management
Integrative Learning	This category considered the term integrative learning because it adheres to the proposal of this experimental study, since integrative learning considers the direct connection between conceptual and experiential learning	Florén (2005) Sense (2007) Smyth *et al*. (2010) Hatami (2013) Bhowmick *et al*. (2015) Wiewiora *et al*. (2020) Chan *et al*. (2021)	Q5	Most biased among the four styles: accommodator, assimilator, convergent or divergent

Distributed Team Cognition	This category considers the DTC theory, when verifying the understanding and application of the concept that distributed cognition occurs through the interaction between individuals, tools, artifacts, and society	Hutchins (1995) Rogers (1997) Hutchins (2000) Hollan *et al*. (2000) Seel (2012)	Q6	Presence or absence of collaborative behaviour, communication and collective interaction, trust building, and social interaction and knowledge building
Collaborative Behaviour	Considering the role of the project team in the PM's view, how does the collaborative behaviour occur	Ligorio *et al*. (2005) Ajayi *et al*. (2016) Poirier *et al*. (2017) Sangwan *et al*. (2020) Schultz *et al*. (2021) Zhang *et al*. (2021)	Q7	Presence or absence of collaborative behaviour
Communication and Collective Interaction	Considering the role of the project team in the PM's view, how does collective interaction and directed communication occur	Dwivedula and Bredillet (2010) Vaux and Kirk (2018) Habouba-Belinky and Parush (2020) Drury-Grogan (2021) Wang *et al*. (2021)	Q8	Presence or absence of communication and collective interaction
Trust Building	Considering the role of the project team in the PM's view, how does the trust building in the cognitive and behavioural components occur	He (2012) Lin *et al*. (2012) Lu and Hao (2013) Han and Hovav (2016) Lu and Yan (2016) Vaux and Kirk (2018) Guo *et al*. (2021) Flyvbjerg (2021) Pavez *et al*. (2021)	Q9	Presence or absence of trust building

Sociocognitive and Knowledge Building	Considering the role of the project team in the PM's view, how does social interaction and knowledge construction occur	Hyldegård (2006) Forgues and Koskela (2009) Liu *et al*. (2022) Loosemore and Chandra (2012) Loch (2017) Chang *et al*. (2021) Chang *et al*. (2013) Small and Walker (2011)	Q10	Presence or absence of social interaction and knowledge building
Collaborative Problem Solving	This category aims to understand how problem solving in the collaborative environment occurs	Hilary & Menzly (2006) Smulders *et al*. (2008) Han and Hovav (2016) Detzen *et al*. (2018) Vaux and Kirk (2018) Williams (2019) Habouba-Belinky and Parush (2020)	Q11	Presence or absence of CPS

A. Script of the interviews:

i. <u>Warm-up / Introduction:</u>

1. Talk about your experience in project management.
2. What is your age?

ii. <u>Questions:</u>

- Question 1: How do you manage projects?
- Question 2: How do you deal with problems that arise during the execution of project tasks?
- Question 3: How does your interaction with the project team members?
- Question 4: How do you manage your stakeholders?
- Question 5: How do you acquire knowledge in your professional environment?
- Question 6: How would you describe access to knowledge among team members?
- Question 7: How would you describe your daily activities in terms of teamwork?

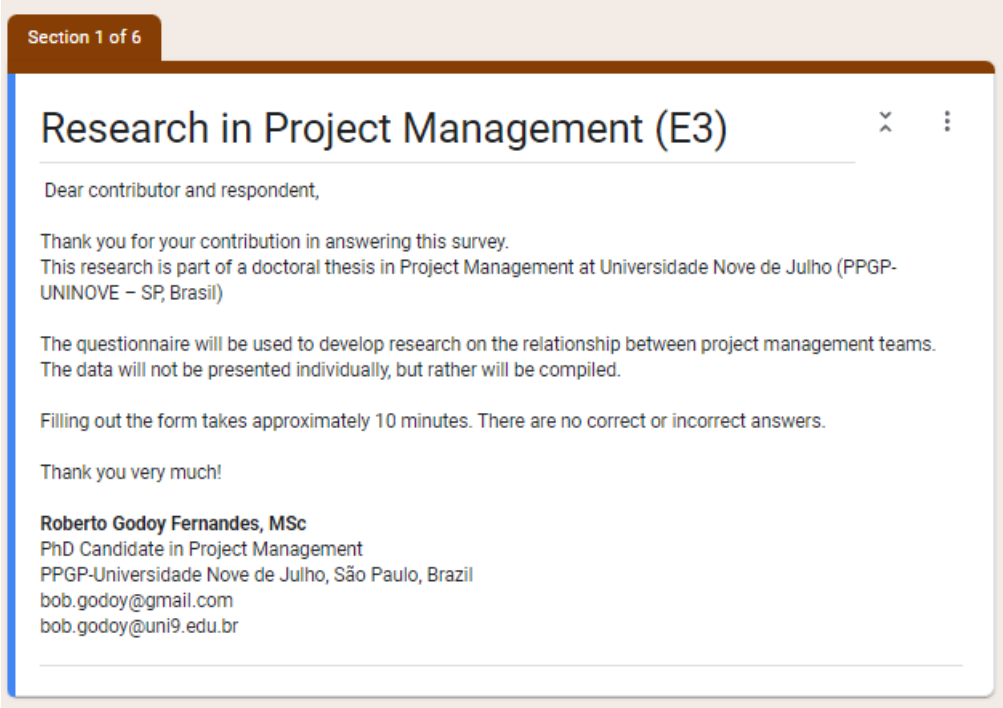
- Question 8: How would you describe the communication with the team members throughout the phases of the project?
- Question 9: How would you describe the level of trust between team members throughout the project?
- Question 10: How would you relate social interaction, access to knowledge and problem solving in projects?
- Question 11: How does the team solve problems collaboratively?

iii. Closing thanks:

I appreciate your availability and your attention throughout the interview. I emphasize that the interview transcription and recording can be requested immediately following the interview, or at any time thereafter. I will inform everyone once the study is published.

APPENDIX B – QUESTIONNAIRE OF STUDY-3

English version



Section 1 of 6

Research in Project Management (E3)

Dear contributor and respondent,

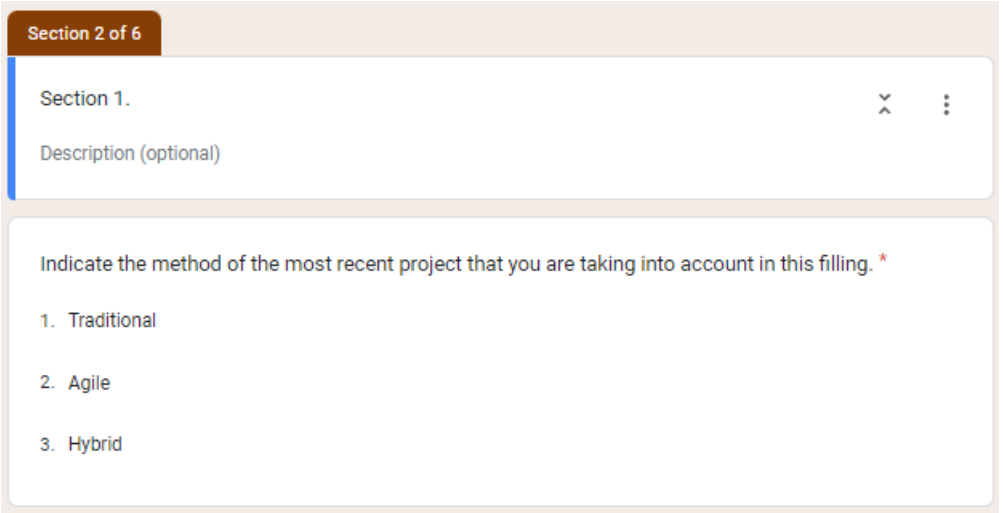
Thank you for your contribution in answering this survey.
This research is part of a doctoral thesis in Project Management at Universidade Nove de Julho (PPGP-UNINOVE – SP, Brasil)

The questionnaire will be used to develop research on the relationship between project management teams. The data will not be presented individually, but rather will be compiled.

Filling out the form takes approximately 10 minutes. There are no correct or incorrect answers.

Thank you very much!

Roberto Godoy Fernandes, MSc
PhD Candidate in Project Management
PPGP-Universidade Nove de Julho, São Paulo, Brazil
bob.godoy@gmail.com
bob.godoy@uni9.edu.br



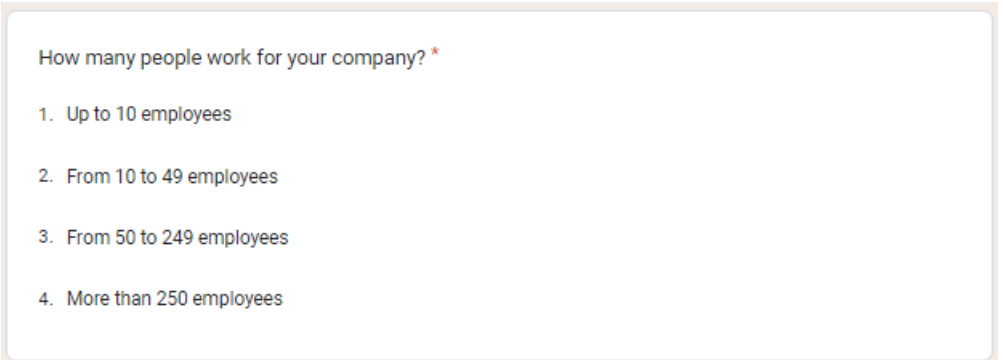
Section 2 of 6

Section 1.

Description (optional)

Indicate the method of the most recent project that you are taking into account in this filling. *

1. Traditional
2. Agile
3. Hybrid



How many people work for your company? *

1. Up to 10 employees
2. From 10 to 49 employees
3. From 50 to 249 employees
4. More than 250 employees

Which category below includes your age? *

1. Up to 19 years
2. From 20 to 29 years old
3. From 30 to 39 years old
4. From 40 to 49 years old
5. From 50 to 59 years old
6. From 60 to 69 years old
7. Over 70 years

Which best describes your gender? *

- ○ Male
- ○ Female
- ○ I prefer not to inform
- ○ Other...

Type your country of citizenship. *

Short answer text

Type the country in which you currently reside. *

Short answer text

What is the highest degree or level of school you have completed? *

- ○ Certification Programs Diploma
- ○ University or Bachelor's Degree
- ○ Postgraduate Diploma
- ○ Master's Degree
- ○ Doctoral Degree
- ○ Postdoctoral Diploma
- ○ Other...

Current job position. *

Short answer text

Currently, do you consider yourself a project manager or project team member? *

- ○ Project manager
- ○ Project team member
- ○ Other...

How many years of professional experience do you have? *

1. Up 2 years
2. From 2 to 4 years
3. From 5 ato 9 years
4. From 10 to 19 years
5. Over 20 years

Section 3 of 6

Section 2.

Description (optional)

Each team member has specialized knowledge of some aspect of our work. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I have knowledge about an aspect of our work that no other team member has. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Different team members are responsible for expertise in different areas. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

The specialized knowledge of several team members is needed to achieve our goals. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I know which team members have expertise in specific areas. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I am comfortable accepting suggestions from other team members. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I trust that other members' knowledge is credible. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I am confident relying on the information that other team members bring to the discussion. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

When other team members give information, I tend to double-check it for myself. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I do not have much faith in other team members' "expertise". *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Our team works together in a well-coordinated fashion. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Our team has very few misunderstandings about what to do. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Our team needs to back track and start over a lot. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

There is often much confusion about how we accomplish our work. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

We tend to accomplish our work smoothly. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

We tend to accomplish our work efficiently. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Section 4 of 6

Section 3.

Description (optional)

If you make a mistake on this team, it is often held against you. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Members of this team are able to bring up problems and tough issues. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

People on this team sometimes reject others for being different. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

It is safe to take a risk on this team. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

It is difficult o ask other members of this team for help. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

No one on this team would deliberately act in a way that undermines my efforts. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Working with members of this team, my unique skills and talents are valued and utilized. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Whenever I've learned something new, I tell the other members of this team about it. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I tell the other members of this team what I know, when they ask me about it. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I tell the other members of this team about my skills, when they ask me about it. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

When they've learned something new, other members of this team tell me about it. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I ask other members of this team what they know when I need particular knowledge. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

The other members of this team tell me what they know, when I ask them about it. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

The other members of this team tell me about their skills, when I ask them about it. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Section 5 of 6

Section 4.

Description (optional)

Most people are basically honest. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Most people are basically good natured and kind. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Most people trust others. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Generally, I trust others. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Most people are trustworthy. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Even though I may sometimes suffer the consequences of trusting someone, I still prefer to trust than not to trust others. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I don't want to do things together with others insofar as there is the slightest possibility that I am the only one to suffer a loss. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I hate to lose because of having counted on someone. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I might be taken advantage of by people sometimes, but I don't mind much. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I feel comfortable justifying recommendations/advice face to face with more senior people. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I feel comfortable explaining an issue to people who are unfamiliar with the topic. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I have difficulty in adapting my communication style (oral and written) to particular situations and audiences. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I prefer to stay quiet when other people in a group express opinion that I don't agree with. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I feel comfortable working in a group. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I feel uncomfortable putting forward my personal opinions in a group. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I feel uncomfortable taking the lead in a group. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I am able to become quickly involved in new teams and groups. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I am comfortable expressing my own opinions in a group, even when I know that other people don't agree with them. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

When faced with a difficult personal problem, it is better to decide yourself rather than to follow the advice of others. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

In general, I do not like to ask other people to help me to solve problems. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I prefer to make decisions on my own, rather than with other people. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I would rather struggle through a personal problem by myself than discuss it with a friend. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I do not like to depend on other people to help me to solve my problems. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I value other people's help and advice when making important decisions. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I like to get advice from my friends and family when deciding how to solve my personal problems. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I prefer to consult with others before making important decisions. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I usually find other people's advice to be the most helpful source of information for solving my problems. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I usually prefer to ask other people for help rather than to try to solve problems on my own. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Section 6 of 6

Section 5.

Dear contributor and respondent,

We would like to thank you for taking the time to complete this electronic form and participate in this survey.

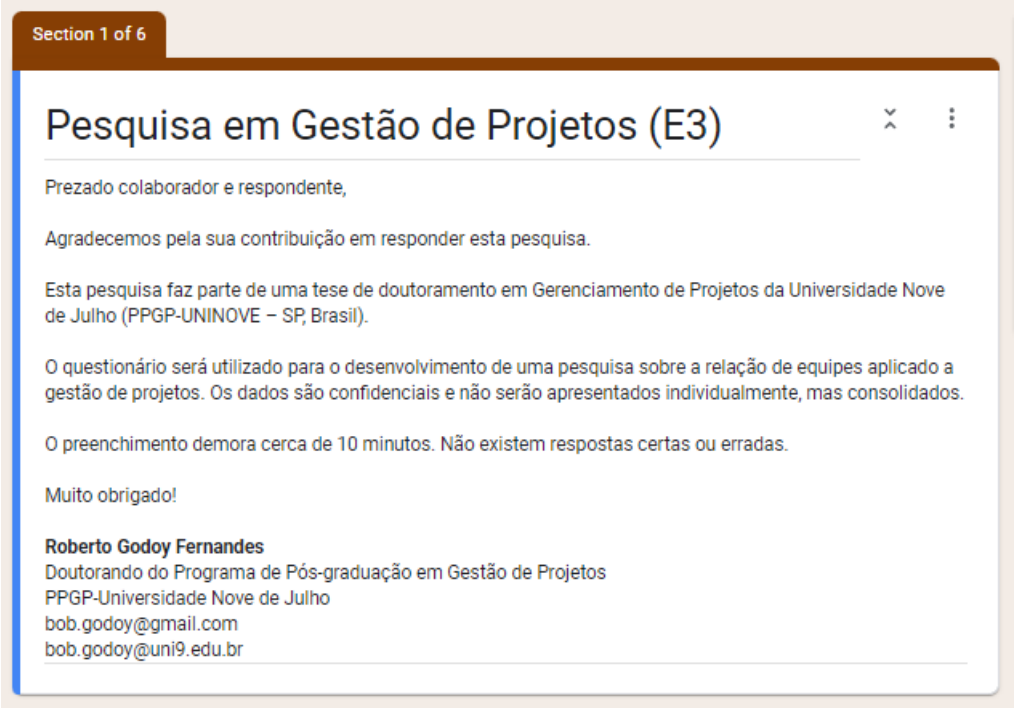
Your contribution is very valuable to us!

Best Regards,
Roberto Godoy Fernandes
PhD Candidate in Project Management
PPGP-Universidade Nove de Julho, São Paulo, Brazil
bob.godoy@gmail.com
bob.godoy@uni9.edu.br

If you desire to provide additional feedback, you may do so below or via one of the email addresses listed above:

Long answer text

Portuguese version



Section 1 of 6

Pesquisa em Gestão de Projetos (E3)

Prezado colaborador e respondente,

Agradecemos pela sua contribuição em responder esta pesquisa.

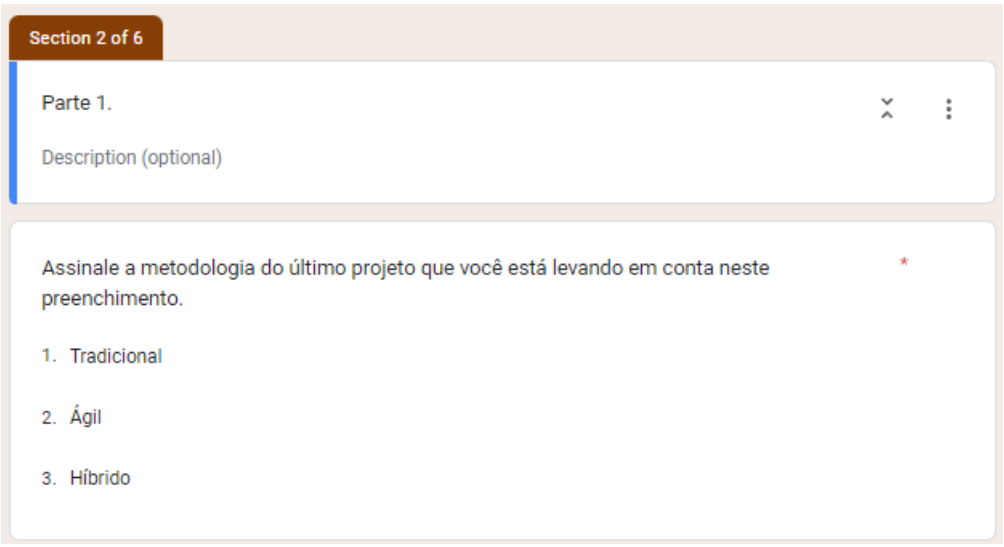
Esta pesquisa faz parte de uma tese de doutoramento em Gerenciamento de Projetos da Universidade Nove de Julho (PPGP-UNINOVE – SP, Brasil).

O questionário será utilizado para o desenvolvimento de uma pesquisa sobre a relação de equipes aplicado a gestão de projetos. Os dados são confidenciais e não serão apresentados individualmente, mas consolidados.

O preenchimento demora cerca de 10 minutos. Não existem respostas certas ou erradas.

Muito obrigado!

Roberto Godoy Fernandes
Doutorando do Programa de Pós-graduação em Gestão de Projetos
PPGP-Universidade Nove de Julho
bob.godoy@gmail.com
bob.godoy@uni9.edu.br



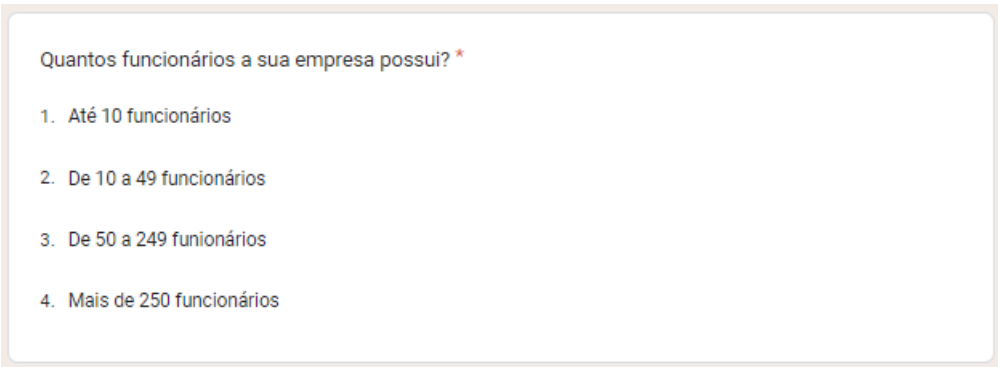
Section 2 of 6

Parte 1.

Description (optional)

Assinale a metodologia do último projeto que você está levando em conta neste preenchimento. *

1. Tradicional
2. Ágil
3. Híbrido



Quantos funcionários a sua empresa possui? *

1. Até 10 funcionários
2. De 10 a 49 funcionários
3. De 50 a 249 funionários
4. Mais de 250 funcionários

Idade. *

1. Até 19 anos
2. De 20 a 29 anos
3. De 30 a 39 anos
4. De 40 a 49 anos
5. De 50 a 59 anos
6. De 60 a 69 anos
7. Acima de 70 anos

Sexo. *

- ( ) Masculino
- ( ) Feminino
- ( ) Prefiro não informar
- ( ) Other...

Digite o seu país de nacionalidade. *

Short answer text

Digite o seu país de residência atual. *

Short answer text

Informe o seu maior nível de escolaridade. *

- ( ) Técnico
- ( ) Superior
- ( ) Especialização ou MBA
- ( ) Mestrado
- ( ) Doutorado
- ( ) Pós-Doutorado
- ( ) Other...

Cargo atual. *

Short answer text

Atualmente, você se classifica como gestor/gerente de projetos ou membro da equipe de projetos? *

- ( ) Gestor / Gerente de projetos
- ( ) Membro de uma equipe de projetos
- ( ) Other...

Quantos anos de experiência profissional você tem? *

1. Até 2 anos
2. De 2 a 4 anos
3. De 5 a 9 anos
4. De 10 a 19 anos
5. Acima de 20 anos

Section 3 of 6

Parte 2.

Pensando na equipe em que você faz parte, por favor indique quanto você concorda com as afirmações abaixo, sendo 1 discorda totalmente e 7 concorda totalmente.
Considere o último projeto que você participou e leve em conta a sua atuação.

Cada membro da equipe possui conhecimento especializado em algum aspecto do nosso trabalho. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Eu tenho conhecimento sobre um aspecto do nosso trabalho que nenhum outro membro da equipe tem. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Quando outros membros da equipe fornecem informações, eu costumo verificar por mim mesmo. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Diferentes membros da equipe são responsáveis por conhecimentos em diferentes áreas. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

O conhecimento especializado de vários membros da equipe é necessário para atingir nossos objetivos. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Nossa equipe trabalha em conjunto de forma bem coordenada. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Nossa equipe tem muito poucos mal-entendidos sobre o que fazer. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Eu sei quais membros da equipe têm experiência em áreas específicas. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Eu me sinto confortável em aceitar sugestões de outros membros da equipe. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Nossa equipe precisa voltar atrás e recomeçar algo com frequência. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Tendemos a realizar o nosso trabalho de maneira suave. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Tendemos a realizar o nosso trabalho de maneira eficiente. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Eu acredito que o conhecimento dos outros membros da equipe seja confiável. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Confio nas informações que outros membros da equipe trazem para a discussão. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Frequentemente há muita confusão sobre como realizamos o nosso trabalho. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Não confio muito na experiência dos outros membros da equipe. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Section 4 of 6

Parte 3.

Pensando na equipe em que você faz parte, por favor indique quanto você concorda com as afirmações abaixo, sendo 1 discorda totalmente e 7 concorda totalmente.
Considere o último projeto que você participou e leve em conta a sua atuação.

Se você cometer um erro nesta equipe, frequentemente ele será usado contra você. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Sempre que aprendo algo novo, digo aos outros membros da equipe sobre isso. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Eu conto aos outros membros da equipe o que eu sei, quando eles me perguntam sobre isso. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Eu conto aos outros membros da equipe sobre minhas habilidades, quando eles me perguntam sobre isso. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Quando aprendem algo novo, outros membros da equipe me falam sobre isso. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

É difícil pedir ajuda a outros membros desta equipe. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Pergunto aos outros membros da equipe o que eles sabem quando preciso de um conhecimento específico. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Os outros membros da equipe me contam o que sabem, quando eu pergunto a eles sobre isso. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Ninguém nesta equipe agiria intencionalmente de forma a prejudicar os meus esforços. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Trabalhando com os membros desta equipe, minhas habilidades e talentos são valorizados e utilizados. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Os outros membros da equipe me falam sobre suas habilidades, quando eu pergunto a eles sobre isso. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Os membros desta equipe são capazes de trazer problemas e questões difíceis. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

É seguro se arriscar nesta equipe. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

As pessoas nesta equipe às vezes rejeitam os outros por serem diferentes. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Section 5 of 6

Parte 4.

Pensando na equipe em que você faz parte, por favor indique quanto você concorda com as afirmações abaixo, sendo 1 discorda totalmente e 7 concorda totalmente.
Considere o último projeto que você participou e leve em conta a sua atuação.

Sou capaz de me envolver rapidamente em novas equipes e grupos. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Não quero fazer coisas junto com os outros na medida em que houver a menor possibilidade de ser o único a sofrer uma perda. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Prefiro consultar os outros antes de tomar decisões importantes. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Sinto-me confortável em expressar minhas opiniões em um grupo, mesmo quando sei que outras pessoas não concordam com elas. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Odeio perder por ter confiado em alguém. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Eu me sinto desconfortável em liderar um grupo. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Gosto de receber conselhos de meus amigos e familiares ao decidir como resolver meus problemas pessoais. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Eu me sinto desconfortável em expor minhas opiniões pessoais em um grupo. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Geralmente prefiro pedir ajuda a outras pessoas à tentar resolver os problemas sozinho. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Mesmo que às vezes sofra as consequências de confiar em alguém, ainda assim prefiro confiar à não confiar nos outros. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Eu valorizo a ajuda e conselhos de outras pessoas ao tomar decisões importantes. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Eu me sinto confortável trabalhando em grupo. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Não gosto de depender de outras pessoas para me ajudar a resolver meus problemas. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Prefiro ficar quieto quando outras pessoas em um grupo expressam opiniões com as quais não concordo. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Prefiro enfrentar um problema pessoal sozinho à discuti-lo com um amigo. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Geralmente, eu confio nos outros. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Prefiro tomar decisões sozinho à envolver outras pessoas. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Tenho dificuldade em adaptar o meu estilo de comunicação (oral e escrita) em determinadas situações e públicos. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Normalmente considero o conselho de outras pessoas a fonte de informação mais útil para resolver meus problemas. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

As pessoas podem tirar vantagem de mim às vezes, mas não me importo muito. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Sinto-me à vontade para explicar um problema a pessoas que não estão familiarizadas com o assunto. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Em geral, não gosto de pedir ajuda a outras pessoas para resolver problemas. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Diante de um problema pessoal difícil, é melhor decidir por si mesmo à seguir o conselho de outras pessoas. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Sinto-me à vontade para receber conselhos face a face com pessoas mais experientes. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

A maioria das pessoas confia nos outros. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

A maioria das pessoas é confiável. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

A maioria das pessoas é honesta. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

A maioria das pessoas é de boa índole e gentil. *

	1	2	3	4	5	6	7	
Discordo totalmente	○	○	○	○	○	○	○	Concordo totalmente

Section 6 of 6

Parte-5.

Prezado colaborador e respondente,

Gostaria de agradecer pelo tempo gasto em preencher este formulário eletrônico e participar desta pesquisa.

A sua contribuição é muito valiosa para nós!

Atenciosamente,

Roberto Godoy Fernandes
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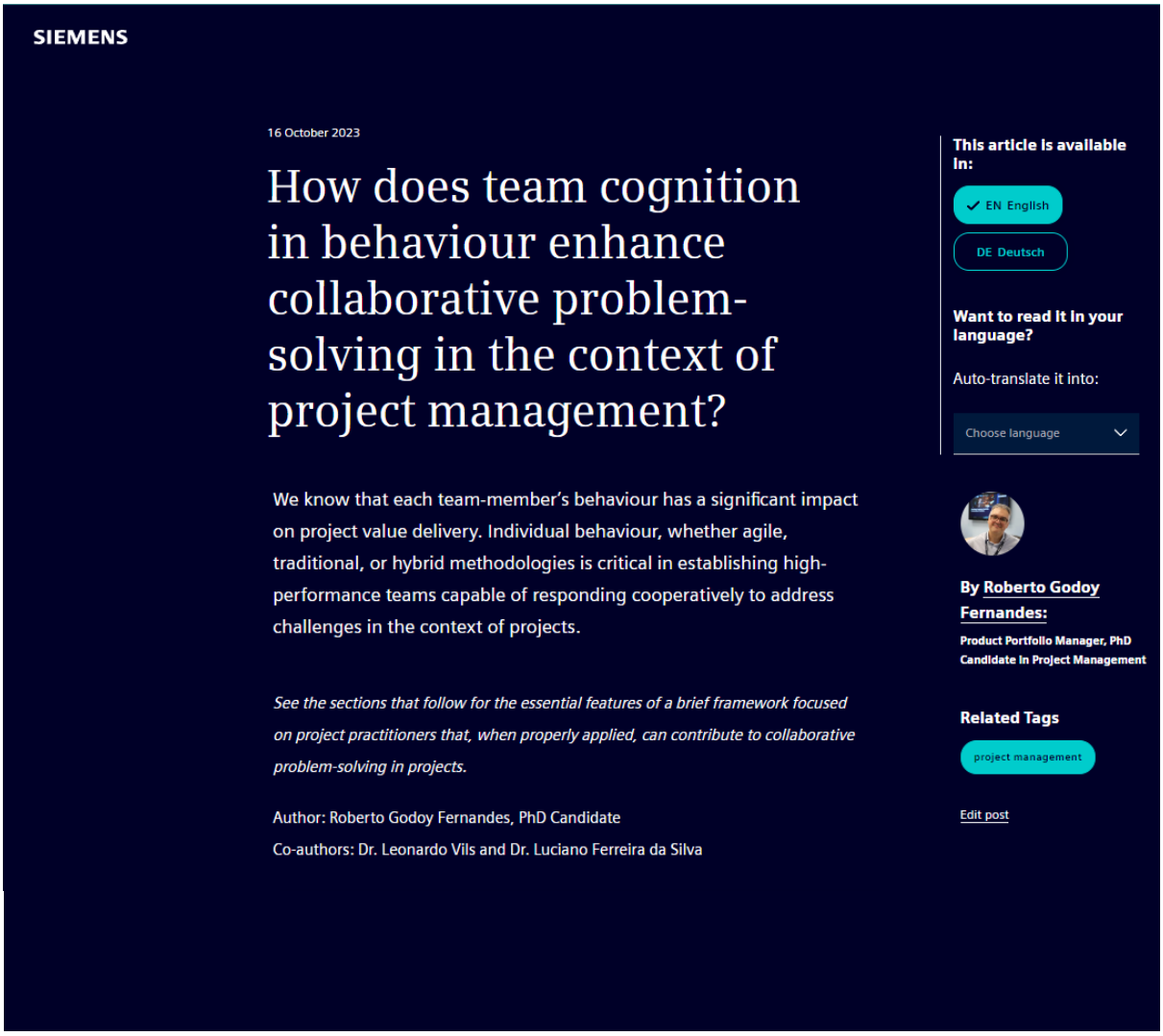
Caso deseje deixar algum comentário adicional, sinta-se a vontade para fazê-lo a seguir, ou via um dos e-mails informados.

Long answer text

ANNEX A – PUBLICATION OF THE TECHNICAL-TECHNOLOGICAL PRODUCT ON THE SIEMENS WEBSITE (GERMANY)

Available at: https://blog.siemens.com/2023/10/how-does-team-cognition-in-behaviour-enhance-collaborative-problem-solving-in-the-context-of-project-management/



SIEMENS

16 October 2023

How does team cognition in behaviour enhance collaborative problem-solving in the context of project management?

We know that each team-member's behaviour has a significant impact on project value delivery. Individual behaviour, whether agile, traditional, or hybrid methodologies is critical in establishing high-performance teams capable of responding cooperatively to address challenges in the context of projects.

See the sections that follow for the essential features of a brief framework focused on project practitioners that, when properly applied, can contribute to collaborative problem-solving in projects.

Author: Roberto Godoy Fernandes, PhD Candidate
Co-authors: Dr. Leonardo Vils and Dr. Luciano Ferreira da Silva

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By Roberto Godoy Fernandes:

Product Portfolio Manager, PhD Candidate in Project Management

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Introduction

The importance of problem-solving within project management is widely recognised, regardless of the specific methodology employed (Drury-Grogan, 2021; Ribeiro *et al.*, 2021). The process of problem-solving involves the systematic application of methods and tools in order to address and resolve problems, regardless of whether they are of a known or unknown nature (Barrett, 2018). Collaborative problem-solving is identified as a behavioural aspect that has an impact on both professional performance and individual well-being (Zheng *et al.*, 2020). The problem-solving is regarded as a highly significant skill in the context of the 21st century. This skill encompasses various components, including: (i) comprehending the essence of the problem; (ii) delineating the stages involved in resolving the problem; (iii) selecting the most optimal strategy for resolution; (iv) specifying the sources of data and compiling a comprehensive list of information required for resolution; and (v) monitoring the successful resolution of the problem (Aslan, 2021).

Recent findings data show that collaborative problem-solving is enhanced by distributed team cognition, which in turn is affected by the influence of environmental factors, contextual elements, and social interactions (Fernandes *et al.*, 2023). In this same study, it is explored that enhancement of collaborative problem-solving by the distributed team cognition, which involves team-oriented communication strategies that utilise both collective and individual messages seek to encourage collective interaction among team-members, and so, explores the influence of collective interaction on the trust building within the team, and how trust building subsequently affects collaborative behaviour.

> **Possibly, you may be asking yourself: How does distributed cognition affect human behaviour? And how does all this impact collaborative problem-solving in project management?**

To answer both questions, I would like to invite you to continue the journey with me, beginning with the presentation of researcher Edwin Hutchins, professor and former of the cognitive sciences department at the University of California, San Diego. Based on his studies, cognition is an antecedent to behaviour and pertains to how individuals interact with one another in each context (Barrett, 2018; Rouleau *et al.*, 2021). Everyone's cognition encompasses the mental processes of acquiring knowledge and understanding through human thought, experience, and senses, and is related to input, storage, and how the learned information can be applied to guide human behaviour (Cambridge Cognition, 2015). Hutchins elucidates that individual cognition can be enhanced by distributed team cognition, and so, demonstrates that the behavioural process is related to how individuals interact with each other and with their environment and contexts (Hutchins, 1995, 2000).

Implementing effective management strategies is crucial for promoting the development of problem-solving skills in a collaborative team. The presence of collaborative problem-solving within the project environment and its various contexts is a crucial element that enhances performance in the problem-solving process and the successful delivery of outcomes (Yu and Lou, 2022). The management and conduct of projects benefit from having a collaborative problem-solving oriented behaviour because it improves the detection of issues and their underlying causes, encourages team-members to contribute their best solutions, and maximises project planning and execution (Hong *et al.*, 2020). When an individual chooses to act independently, they may encounter more challenges in determining the appropriate approach for resolving a situation. On the other hand, collaborative action tends to yield better outcomes due to the synergistic effect of collective understanding and joint efforts (Newton *et al.*, 2018; Hong *et al.*, 2020).

> The management and conduct of projects benefit from having a collaborative problem-solving oriented behaviour because it improves the detection of issues and their underlying causes, encourages team-members to contribute their best solutions, and maximises project planning and execution (Hong *et al.*, 2020).

The management of a team following the collaborative problem-solving approach presents relevant benefits, such as improved task organisation, integration of diverse perspectives, experiences, and sources of knowledge, and the generation of creative outcomes through collective performance (Hou *et al.*, 2021). Hence, collaborative problem-solving influences and is influenced by trust building, team communication and collaborative behaviour, which is further potentialized by the presence of psychological safety. Given the involvement of all relevant stakeholders throughout the appropriate project phases, it remains crucial to consider the concept collaborative problem-solving as it plays a significant role in the anticipation of risks, identification of opportunities, and potential changes.

A brief framework for practicioners

Figure 1 and the following text illustrate each element of the proposed framework intended for project management practitioners.

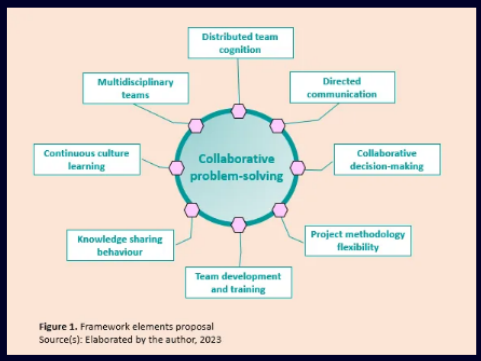

Figure 1. Framework elements proposal
Source(s): Elaborated by the author, 2023

1. Distributed team cognition: To begin, as previously pointed out, recognise the influence of distributed team cognition. In practise, acquired and applied knowledge, intelligence, and decision-making extend beyond individuals to the whole team, a multidisciplinary team. Several studies support this concept, such as: (i) Cognitive intelligence and project success-oriented cognitive skills include analytical, organisational, critical thinking, and creative skills (Agarwal *et al.*, 2023); (ii) Cognitive style diversity affects team implicit learning (Agarwal *et al.*, 2019); (iii) Cognition is linked to decision-making in terms of trust (Shealy and Hu, 2018).

***2. Multidisciplinary teams, always*:** It all starts with the reality that project teams, more than any other professional or knowledge sector, are multidisciplinary by definition (Urton and Murray, 2021). As a result, it is critical that members have a diverse set of skills, expertise, and experiences. As a result, it will enable an effective distribution of cognition from various perspectives (LaFrance *et al.*, 2019; Urton and Murray, 2021).

3. Directed communication: Encourage open and honest communication among team-members. This enables for the open sharing of knowledge and expertise. Communication is ineffective in and of itself, but efficient communication is communication tailored to each team-member and stakeholder in a way that can reduce tensions and conflicts while simultaneously building trust (Fernandes *et al.*, 2023).

The importance of communication and knowledge sharing within distributed team cognition is highlighted when looking at multidisciplinary teams involved with collaborative problem-solving, considering that proximity management and interpersonal interactions promote cognitive proximity, knowledge exchange, idea development, and mutual learning (LaFrance *et al.*, 2019).

***4. Continuous culture learning*:** Culture must be formed from elements that contribute to the establishment of an environment that includes: (i) collaboration tools that facilitate information exchange (Drury-Grogan, 2021; Ribeiro *et al.*, 2021); and (ii) continuous learning within the team, in both formal and informal environments, to facilitate knowledge sharing and the ability to learn from errors, in an environment where project managers ensure psychological safety (Clark, 2020; Ahiaga-Dagbui, 2020).

5. Knowledge sharing behaviour: It is true that high performance project teams are collaborative and have a high capacity to share knowledge, and the more ability the project manager must generate and maintain an environment of psychological safety, the building of trust is developed and improved, and so on, quality knowledge is generated (Ahiaga-Dagbui, 2020). Psychological safety is an ally in this 'bridge' to knowledge since it refers to an individual's perceptions about the potential results and consequences of the interpersonal risks to which they are exposed (Xu and Suntrayuth, 2022).

> Create an environment that attempt to build trust and is psychologically safe; this environment will enhance your communication process, the generation of new ideas, the effective exchange of knowledge, creativity, and innovation among project team-members (Brasier, 2023; Xu and Suntrayuth, 2022; Ghazinejad *et al.*, 2018).

Distributed team cognition improves collaborative problem-solving competence (Hagermann and Kluge, 2017; Graesser *et al.*, 2018). There is no creativity or innovation in technological companies without high levels of engagement, collaboration, and knowledge exchange (Hong *et al.*, 2022). The project manager is the protagonist throughout this entire process; he is the first layer of quality, the spokesperson, and the one who built this "bridge." As a result, outcomes are influenced by the leadership style (transformational or authoritative) (Jiang and Chen, 2021).

6. Project methodology flexibility: To achieve project success with adequate value delivery, it is critical to recognise that diverse projects, challenges, delivery levels, complexity, and customer culture may necessitate different approaches. Be flexible

7. Collaborative decision-making: Involve and empower all team-members in decision-making processes to identify better solutions through incorporating their different perspectives and knowledge through reflecting the competence and effort of other people (Xiang *et al.*, 2023). It has previously been demonstrated that the brain has cognitive and behavioural processes (Rouleau *et al.*,2021). This because cognition acts as an input process, while behaviour provides as an output process, occurring after decision-making that was affected by distributed team cognition (Barrett, 2018; Rouleau *et al.*, 2021).

In practise, decision-making process incorporates both intuition and perception as cognitive processes. When going from perceptual procedural cognitive to explicit knowledge, the intuitive side incorporates important processes of situational pattern recognition, learning, and tacit knowledge (Patterson, 2017). Multidisciplinary project teams with appropriate cognitive diversity have better creative capacity and deliver more value with decision-making (Drury-Grogan, 2021; Aggarwal and Woolleyb, 2019).

8. Team development and training: Engage in training and development that will improve the team's individual and collective distributed cognition capabilities. Throughout the projects, document the team's experiences and lessons learned. This will contribute to the common knowledge for future projects. Training must be consistent and well-structured, always with a practical and experiential focus, and tailored to the specific needs of each team, considering the challenges of the environment and project contexts (Xiang *et al.*, 2016). Training enables to develop and increase cognitive and emotional intelligence, which can be developed through practical and experiential training (Xiang *et al.*, 2016).

This increases the probability of behavioural integration at the team level (Detzen *et al.*, 2018). Furthermore, training and learning may assist in the development of interpersonal abilities that reduce behavioural tensions and conflict (Smulders *et al.*, 2008; Hilary and Menzly, 2006). Relevant subjects such as communication and feedback must be discussed using concrete instances and lessons acquired from previous projects. At last, since distributed team cognition considers the interaction of people, the environment, contexts, and artefacts, training should aim at creating a continuous process that reinforces interpersonal interactions of attribution of sensegiving and sensemaking, artefacts such as planning, and involvement between communication and its artefacts (Jenkin *et al.*, 2019).

Application Examples

As pointed out in the article, distributed team cognition improves collaborative problem-solving capacity. This occurs through improved utilisation of team-members' individual knowledge and capabilities, which, through knowledge sharing behaviour, collaborative discussions, as well as the integration of different perspectives, the team-members becomes able to achieve better visibility into a situation-problem. Consequently, problem-solving can be achieved in a creative and effective approach through collaborative way resulting from synergy and collective behaviour. Considering the management of complex project teams as an illustration, we have:

- ***R&D – Software development with remote teams:*** In software development projects including remotely distributed teams, even globally, participants from various countries, cultures, and expertise can contribute their talents and, abilities and competencies. Distributed team cognition enables these teams to overcome the challenges of distance, language, and cultural barriers while managing problems related to collaboration, code development, testing, and quality development.
- ***Development of smart infrastructure projects and megaprojects***: The project field itself encompasses multidisciplinary teams, which offers a wide possibility for diversity of individual talents. Projects, such as high-speed rail systems, hospitals, airports, seaports, and offshore oil extraction, demand a multidisciplinary team due to the interdisciplinarity of tasks, with teams composed of support areas (for instance, logistics, quality, EHS, sales), specialists in each project discipline (for instance architecture, electrical, automation, civil), and strategic (for instance finance and commercial project management), fully dedicated and directed, respecting each phase of the project, orchestrated to work in an integrated manner. Therefore, by implementing distributed cognition, each team-member can contribute with their experiences, capabilities, and skills to deliver value, resulting in an increased capacity to collaboratively problem-solving, thereby delivering optimised, sustainable, and innovative solutions.

Conclusion

This study demonstrated that distributed team cognition is an essential element for the success of multidisciplinary teams since it considers the team's ability to understand and process information collaboratively, as well as how the context may impact this altogether. It is no surprise that one of the most important medical findings in the last 50 years has been that the context of the environment influences patient healing and/or recovery. A culture of continuous learning and knowledge sharing behaviour are essential components for improving team-cognition and promoting the effectiveness of engaged work, and consequently the capacity to collaborative problem solving.

Directed communication, combined with the trust building, enhances team cohesion, and allows team-members to knowledge sharing behaviour more effectively. One of the 'organic' results of this knowledge sharing behaviour is the shared decision-making process, which allows the team-members to make informed and shared decisions that are consistent with the general goals and project objectives. Furthermore, team development and continuous training are strategy advances that lead to the continuous enhancement of team cognition. However, it is the project manager's responsibilities and competence to assure experiential training, stimulate collaboration, build an environment for learning, and establish the 'bridge' towards trust building within the multidisciplinary team.

Understanding distributed team cognition provides advantages that enhance collaborative problem-solving behaviour. In terms of its application to project team management, we have:

- ***Continuous learning***, which considers the combination of specialised knowledge and experiences for a shared and collective work model. Consolidated by coexistence in the project, experientiality between projects, action among team-members, artefacts and contexts that enhance individual and group skills.
- Better ***decision-making*** through diversity of approaches, based on different training and skills that produce multiple perspectives and decisions that are more well-informed and logical.
- Efficient ***problem-solving***, combining the elements of this brief framework that encourage innovative thinking, the exploration of unconventional solutions, fostering creativity, delivering value in a more agile manner, and thereby decreasing the time required to find and implement efficient solutions.

We invite you to reflect on each of the presented elements and their applicability, applying them to other contexts. This article is an excerpt from a larger study that aims to provide tools for enhancing collaborative problem-solving capacities. In this context, we also encourage you to continue this conversation on other channels and/or access the entire study, which will be available shortly.

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