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# ENGINEERING TEAM SUCCESS: EVALUATING PERCEPTIONS OF TEAM PROCESSES AND EMERGENT STATES EFFECTS ON TEAM OUTCOMES

A Dissertation Presented to the Graduate School of Clemson University

In Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy Industrial-Organizational Psychology

> by Lauren D. Kistler May 2024

Accepted by: Dr. Robert Sinclair Committee Co-Chair Dr. Marissa Shuffler Committee Co-Chair Dr. Jennifer Ogle Dr. Patrick Rosopa Dr. Matthew Cronin

#### ABSTRACT

The increasing reliance on teams in modern organizations demonstrates the value and relevance of teamwork in the professional world (Porter et al., 2003). Despite the substantial amount of team research focused on team effectiveness (Mathieu et al., 2008), further investigation is warranted to provide more nuanced insight into team dynamics. The present study examined perceptions of team processes and emergent states to assess how they impact perceptions of team satisfaction and potency. Perceptions of strategy formulation, role clarity, team monitoring and backup, monitoring goal progression, coordination, trust, psychological safety, team potency, and team satisfaction were measured with a sample of 114 student teams (444 students). The assessments also provided qualitative team feedback. Data were collected at the midterm and end of the semester. Results showed that team members' perceptions of strategy formulation, role clarity, team monitoring and backup, monitoring goal progression, coordination, and psychological safety were positively related to perceptions of team potency. Findings also indicated that team members' perceptions of cooperative conflict management, trust, and psychological safety were positively related to perceptions of team satisfaction. Results provide support for the notion that compared to the perception of the team emergent states at time one, the perceptions at time two would have a stronger influence on perceptions of team satisfaction at time two and partial support for this effect on team potency. Using Natural Language Processing (NLP) to analyze the qualitative data supplemented the quantitative analysis by uncovering themes pertaining to underlying mechanisms of teamwork. The findings of the present study provide important insight

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into how perceptions of team processes and emergent states influence team outcomes, highlight the importance of time within team research study designs, and demonstrate the value of integrating NLP methods to analyze qualitative data.

# DEDICATION

To my brother and my parents. Thank you for your support throughout this entire process, it has allowed me to achieve my greatest aspiration.

To my best friend. Thank you for being there through every stage of my life with encouragement, love, and comedic relief.

To Aspen. Thank you for your unwavering emotional support and for making me walk away from my desk at least three times a day.

#### ACKNOWLEDGMENTS

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#### CHAPTER ONE

#### INTRODUCTION

Teams of people working together are an integral part of modern life. Daily activities such as postal delivery, emergency responses (e.g., firefighting), and public transportation are carried out by teams. Teams of individuals working together toward a common goal are at the center of human social structure (Kozlowski & Ilgen, 2006). From tee ball leagues to academic group projects to top management, team experiences permeate peoples' experiences throughout various stages of life (Kozlowski & Ilgen, 2006; Cannon-Bowers & Bowers, 2011). Team activities are a way for people to connect socially, develop their individual skill sets, and build interpersonal relationships. Being able to work successfully within a team is a strength for people to continuously develop throughout their life experiences. It is imperative for individuals to develop their ability to meaningfully contribute to a team as early as possible to utilize their teamwork skills throughout their careers.

The vast amount of extant team research paired with the incorporation of teambased designs in organizations highlights the importance of understanding what drives teams to function effectively. Factors influencing team functioning have received substantial attention from researchers and practitioners alike. Contributing factors include team processes, which are coordinated actions among team members to achieve a collective goal (Marks et al., 2001). Processes represent mechanisms that enable or inhibit team members' ability to effectively use their combined knowledge and skills to accomplish tasks or goals (Kozlowski & Bell, 2003). An example of a team process is goal specification, which involves the development of a team's overall goals and subgoals including specification of criteria for quality and completion.

Group research has evolved for over fifty years from the initial guiding frameworks developed by McGrath (1964) and Hackman and Morris (1975) to the notable team process taxonomy delineated by Marks et al. (2001) and revision of the input-process-output model by Ilgen et al. (2005) to more recent advancements emphasizing the dynamic nature of teams (Cronin et al., 2011; Kozlowski & Chao, 2018). Team research has examined antecedents and consequences of team processes at the individual, team, and organizational level (LePine et al., 2008; Newnan et al., 2017). The results of research examining teams spanning several decades have led to theoretical and empirical developments (e.g., Cannon-Bowers & Bowers, 2011; Cohen & Bailey, 1997; Hackman & Morris, 1975; Marks et al., 2001; Weldon et al., 1991).

Despite the extensive research on teams and team processes, reviews of the existing team literature (e.g., Breuer et al., 2016; LePine et al., 2008; Mathieu et al., 2017) have suggested that future research is needed to improve the understanding of team constructs and the extent to which various team processes affect team outcomes. Team research would benefit from such research because proper specification of constructs would enable researchers to make accurate inferences from empirical tests of theoretically derived relationships (Edwards, 2001; LePine et al., 2008). LePine and colleagues (2008) argued that there is a need for empirical research to clarify the nature of team processes and the results of such efforts could yield a better understanding of the

constructs and subsequently enhance the development of practices intended to improve team effectiveness.

Investigators must account for emergent states, in addition to team processes and outcomes, to comprehensively understand teamwork. To understand what makes teams perform, there exists a need to understand, in a sense, the conditions into which they settle – these are the emergent states that come from prior team interactions, and they set the team along pathways that can be (counter)productive. Marks and colleagues (2001) emphasized their distinction from team processes noting that emergent states are products of team experiences. Recognition of the distinctions among team processes, emergent states, and other team characteristics is critical to refine the conceptualization of team processes and avoid construct confusion (Marks et al., 2001). Similar to LePine et al.'s (2008) call for additional research, Mathieu et al. (2017) noted there is extant research on team processes and emergent states, yet there is not a clear understanding of the "unique contributions of different processes, and different states, to the prediction of team outcomes at different times" (p. 460). The present study aimed to provide clarity by investigating the unique relationships between team processes, emergent states, and team outcomes.

Studies focusing on teams and related research areas have also provided managerial implications. Within organizations a majority of the work is completed through teamwork (Marks et al., 2001). Therefore, understanding how teams operate is beneficial for researchers and practitioners in order to provide best practice recommendations. Measuring how and when team processes occur and states emerge can

provide perspective on team dynamics and ultimately identify means to enhance team effectiveness.

Measurement of team performance is only part of the puzzle. Providing feedback is another critical component of advancing team performance. According to Gabelica et al. (2012), providing feedback to teams involves communicating information about their actions, behaviors, processes, and performance to the team members or team. It has been argued that feedback serves as a powerful tool that influences team learning and team performance (Kozlowski & Ilgen, 2006). Providing feedback can reinforce effective behaviors or discourage ineffective behaviors (London, 2003). Feedback can be used to focus attention on the end results of an activity or process, inform team members when they stray from initial goals, assist in the adjustment to new goals, direct team activities, and encourage critical reflection on tasks and circumstances to generate new strategies (Gabelica et al., 2012). Therefore, collecting and subsequently providing feedback can benefit teams.

Team assessments provide a mechanism through which instructors, researchers, and managers can acquire this valuable feedback information. The present study utilized a team health assessment to collect data on teams including individual- and team-level feedback. In addition to gaining contextual insight from the open-ended feedback, utilizing a team assessment is intended to provide useful information to the course instructors and students. They can use the feedback to monitor progress, make adjustments, or pinpoint problematic behaviors to assist in goal attainment. The findings

from subsequent analysis of assessment data can be used to guide future use of assessments to maximize their effectiveness.

In the realm of higher education, particularly within engineering programs, the cultivation of effective teamwork skills is a fundamental yet often overlooked component of student development. Recognizing the vital importance of teamwork in engineering and many other fields, the present study was designed to provide insight into the relationships between perceptions of team processes and emergent states and team outcomes within the context of a civil engineering program. This study examined the relationships between perceptions of fundamental team processes and team emergent states and analyzed their impact on perceptions of team potency and satisfaction. The significance of this study lies in its ability to offer valuable insights for departmental leaders, program faculty members, and students to enhance team effectiveness. The outcomes of this research can potentially be used to guide the development of targeted interventions, training programs, and best practices, ultimately fostering higher-performing teams, enriched with a sense of accomplishment and satisfaction.

# **Benefits of using Peer Feedback Systems**

Peer feedback systems are useful tools within academia and research. Educators, students, and researchers can benefit from the use of peer feedback systems. The feedback system can be used to administer assessments throughout the duration of a semester-long project allowing both instructors and students to monitor team progress and performance. Researchers can use data collected through peer feedback systems to examine team dynamics and provide applied solutions for enhancing teamwork.

In response to an absence of tools for providing team dynamic feedback, O'Neill and colleagues (2018) developed a scalable peer feedback system for learning teams: ITP Metrics. This is a free online platform that provides teamwork and behavioral assessments. O'Neill and colleagues (2018) provide a comprehensive list of compelling reasons to use peer feedback software systems in post-secondary education. They argue that accreditation requirements, career success prioritization, employer demands, preparedness gap, course structure, and efficiency and automation are key drivers supporting the use of peer feedback software systems in higher education. Accreditation agencies, such as the Accreditation Board of Engineering and Technology (ABET), now mandate the development of teamwork skills in graduates, necessitating effective tools for achieving this goal (O'Neill et al., 2018). According to ABET, focusing on continuous improvement as part of assessing student learning is key to ensuring the quality of educational programs and preparing graduates to enter a global workforce.

To further support their claim, O'Neill and colleagues (2018) highlighted research from Passow et al. (2012) and Passow et al. (2017) suggesting that both students and instructors consider teamwork as the most critical attribute for success in careers. Teamwork remains a critical foundation for how work is conducted in organizations, underlining its continued relevance in the professional world (O'Neill & Salas, 2018). Employers have become increasingly concerned with candidates' competencies and skills. The results of the National Association of Colleges and Employers (NACE) 2023 Job Outlook survey indicated that teamwork skills were amongst the top five attributes sought by employees on candidates resumes, and 61% of employers ranked this attribute

as one of the five most important skills. Furthermore, O'Neill et al. (2018) noted that instructors are increasingly structuring coursework around teams, but they require tools that can support the health and effectiveness of these teams (Britton et al., 2017). The increasing demand for teamwork skills necessitates scalable automation to enhance the efficiency and accuracy of collecting and disseminating feedback from peers, addressing the practical challenges of managing teamwork in large educational settings (O'Neill et al., 2018).

In addition to the myriad of reasons provided by O'Neill and colleagues (2018), there are a handful of additional benefits to utilizing these feedback systems worth highlighting. Scalable peer feedback software systems are efficient; they can streamline the process of collecting, distributing, and managing feedback, saving time for both students and instructors. The ability to provide real-time feedback allows instructors to gauge student team progress and gives students the opportunity to make adjustments and improvements prior to the conclusion of the team project. Receiving feedback during a project provides team members with a better understanding of how the team is functioning and receiving feedback at the end of a project can highlight areas of strength and areas for development, equipping them with knowledge of teamwork skills to carry forward into future team efforts.

Peer feedback assessments developed on software systems are customizable; the customization of feedback criteria is advantageous to the development of an assessment that aligns with specific course objectives and learning outcomes (Mathieu et al., 2020). The use of peer feedback systems facilitates the collection of feedback from a broader

range of peers, providing students with diverse perspectives and insights on their work (Bamberger, 2007). Peer feedback systems enable students' skill development and engagement. Providing peer feedback encourages students to develop critical evaluation and communication skills, which are valuable for their academic and professional growth, and promotes active engagement in the learning process, as students are actively involved in assessing their peers' work and reflecting on their own (Jamieson & Shaw, 2018). In a similar vein, using these systems supports an iterative feedback process, encouraging students to revise and refine their work over time, allowing for continuous improvement. Lastly, the utilization of peer feedback systems is advantageous from a data analytics perspective, providing instructors the opportunity to analyze trends and patterns in the feedback, assisting them with making data-driven decisions to enhance the learning experience. In summary, incorporating scalable peer feedback software into post-secondary education programs can enhance the overall learning experience, promote student engagement and development, and contribute to better educational outcomes.

Feedback software systems, like ITP Metrics, which was used for the present study, can provide assessments to measure team dynamics, conflict management styles, personality, and more. Subsequently, the assessments can be administered to collect scores on team processes and outcome measures and open-text feedback data. The qualitative data collected from open-ended questions can serve as a valuable source of information. Qualitative analysis methods allow researchers to gain insight into team dynamics from the contextual information gathered.

#### **Purpose of Current Study**

The primary objectives of the current research include: (1) advancing theoretical understanding of the complex dynamics of teamwork by investigating how team members' perceptions of team processes (e.g., strategy formulation, role clarity, coordination) and emergent states (e.g., trust, psychological safety) impact subsequent perceptions of team efficiency and satisfaction; and (2) providing research-based recommendations for improvements to the civil engineering curriculum that focus on team skills and provide students with opportunities to develop their abilities to function within teams. The proposed investigation was designed to explore students' perceptions of team processes and emergent states to determine the extent to which these mechanisms impact perceived team potency and team satisfaction. By determining which processes significantly influence different team outcomes, the researcher can equip the program's instructors with this knowledge, subsequently giving them the opportunity to cater the curriculum to target specific teamwork skills. Students benefit from this knowledge by having opportunities while working in student teams to develop these critical teamwork skills.

Engineering programs often focus on building technical skills, and as a result teamwork skills may not receive much attention or are often an afterthought in some programs. Within academia there is an increasing pressure, stemming from evolving industry standards (McKinsey Global Institute (MGI) Report, 2018; Robles, 2012), to focus on teaching soft skills in addition to the core technical skills (Loughry et al., 2014; O'Neill et al., 2020; Ritter et al., 2012). Soft skills include but are not limited to

teamwork skills, interpersonal skills, communication skills, and problem-solving skills. Teamwork abilities rated among the top five traits that employers looked for in a resume, according to the results of the NACE 2023 Job Outlook poll. The increasing demand for teamwork skills necessitates development of these skills prior to entering the workforce. Instructors have begun to organize coursework more around teams (Britton et al., 2017), however, many institutional programs often place greater emphasis on developing students' technical skills. Evidence suggests that upon graduation students are inadequately prepared to fulfill teamwork requirements within organizations (O'Neill et al., 2018). To ensure students' success beyond their education, curriculum initiatives related to soft skills are necessary (Ritter et al., 2012). By teaching about the advantages of teamwork and creating opportunities for students to develop these essential skills, programs can prepare students to be better equipped to function in a team-based world.

The present investigation focused on engineering students because Civil Engineering, as a field, recognizes that teamwork skills are important but are insufficiently addressed. Due to the recognized importance of teamwork skills, many engineering programs are trying to determine the optimal way to teach students these skills during their undergraduate as opposed to on the job later. It is advantageous for students to acquire these skills at the early stage of their careers rather than during their professional careers. Therefore, the current study leveraged data from student engineering teams completing projects that mimic real world team experiences they may encounter on the job.

Another primary goal of this project was to provide research-based recommendations that will guide decisions the faculty make to improve the course curriculum. Through collection of data reflecting students' perceptions of team processes, team emergent states, and team outcomes, it is possible to analyze which processes have the most impact on team outcome measures. It is important to conduct this type of team research at the undergraduate level because it is often true that if there are factors negatively impacting team performance at this level (within student teams), then these factors are also negatively impacting team performance on a greater scale within real world team projects. The results of the present study were used to assist department leaders' efforts to determine which aspect(s) of teamwork departmental efforts should be focused on to enhance students' ability to successfully function and perform within a team.

Furthermore, the innovative integration of an advanced analytical technique, Natural Language Processing (NLP), to analyze qualitative feedback comments adds depth and nuance to the current study's exploration of team processes and emergent states and their effects on team success. By applying topic modeling methods, it was possible to delve into the students' qualitative reflections to uncover themes and insights that quantitative analysis alone might not have revealed. Conducting qualitative analyses to supplement the quantitative analyses also provided an avenue for examining team members' insight including contextual details of the team project experience.

#### **Contributions to Theory and Practice**

The present study contributes to team research by identifying which teamwork skills to target to teach people how to work in teams effectively. Additionally, this study provides insight into the temporal aspect of teamwork by examining the perceptions of team processes and emergent states at two time points to determine if these mechanisms are more prominent at different stages of the project. To achieve these objectives, the present research study assesses students' perceptions of team processes and emergent states in order to provide research-based recommendations for applied solutions (e.g., training, workshops, additional courses focusing on soft skills). The present study advances team research by evaluating these relationships to better understand how these mechanisms influence team interactions and experiences, and provide lessons learned to inform decisions focused on practical ways to improve team behaviors. A key contribution of this research is that it was designed to examine the extent to which perceptions of different team processes and emergent states affect team outcomes at different timepoints (e.g., the midpoint and end of a project) to address the lack of a clear understanding of these relationships (Mathieu et al., 2017). Lastly, the present study intended to uncover which teamwork skills (e.g., communication) are utilized and which contextual factors influenced teamwork throughout the course project by leveraging natural language processing (NLP) techniques to reveal underlying factors not explicitly measured by the assessments.

This study used an empirically validated team dynamics measure that evaluates how well a team is functioning to assess perceptions of teamwork effectiveness and

satisfaction (O'Neill et al., 2018). By employing an assessment with validated scales to measure team processes, emergent states, and outcomes, this study builds upon existing team theory and research (e.g., Marks et al., 2001; Mathieu et al. 2017; McGrath, 1984, LePine et al., 2008; O'Neill et al., 2018, 2019, 2020). The utilization of established scales within the team health assessment (O'Neill et al., 2018), strengthens the reliability and validity of our measurements (Kline, 1999; Taylor, 1999), setting a robust foundation for the current exploration of perceptions of team processes, emergent states, and outcomes.

The application of topic modeling in the current study provides support for using advanced statistical approaches within qualitative analysis. The current study provides a demonstration of how NLP can be integrated into research methodology, an emerging topic of interest within many areas of industrial and organizational (I-O) psychology (Speer et al., 2023). The value of implementing a mixed methods approach (McKim, 2017) is the ability to provide a deeper understanding of the complicated, dynamic nature of teamwork.

During students' academic tenure a unique opportunity exists to focus on teamwork skills and train students in ways that promote their ability to function effectively within a team, ultimately advancing their personal and professional development. Within the context of the civil engineering program, incorporating teamwork skill development into the program curriculum equips students with essential soft skills (in addition to the necessary technical skills) prior to entering the workforce. However, the significance of this research extends beyond the confines of this engineering program and even the academic realm. It has the potential to inform

curriculum design and pedagogical approaches within all academic programs, allowing instructors to develop students' teamwork skills more effectively. By pinpointing specific team processes and emergent states that hinder or enhance team potency and satisfaction, this research can be used to empower educators to tailor their guidance, thereby preparing future professionals to excel not only in technical competence but also in the collaborative dynamics demanded by modern workplaces.

Representing leverage points for practices intended to improve team effectiveness (LePine et al., 2008), team processes have been examined within team research in efforts to determine which team constructs can be targeted to improve team functioning. A better understanding of these team processes, as well as emergent states, could assist in the development of useful practices. By providing a clearer understanding of relationships between team processes, emergent states, and outcomes, the implications of this research can extend to examinations of different types of teams (i.e., teams in professional sectors) and potentially impact team training and team development interventions (Shuffler et al., 2018).

In conclusion, the current study represents a dedicated effort to bridge theory and practice, shedding light on the intricate dynamics of teamwork. This study examined a specific set of team mechanisms in relation to team outcomes and the conditions under which they occur in an effort to contribute to the lack of such causal models in teamwork literature (Cannon-Bowers & Bowers, 2011). This dissertation utilizes both qualitative and quantitative methodologies to identify the nuanced connections between team processes (strategy formulation, role clarity, team monitoring and backup, monitoring

goal progression, coordination, cooperative conflict management), team emergent states (trust, psychological safety), and team potency and satisfaction. By addressing calls for more advanced, mixed-methods research on team processes, emergent states and outcomes, the current study aims to leave a lasting impact on both academic discourse and the professional journey of engineering students, better equipping them with the crucial skills needed to thrive in a collaborative, team-centric world.

#### CHAPTER TWO

#### THEORETICAL BACKGROUND

#### **Team Process Taxonomy**

Before diving into the intricacies of the team process taxonomy developed by Marks et al. (2001), it is important to first understand what constitutes a "team process". Marks and colleagues (2001) defined team processes as "members' interdependent acts that convert inputs to outcomes through cognitive, verbal, and behavioral activities directed toward organizing taskwork to achieve collective goals" (p. 357). Simply put, team processes are the means by which team members work together to achieve a meaningful outcome. With the goal of developing a taxonomy that is applicable to different types of teams and easily comprehensible for applied and research purposes, Marks et al. (2001) created a temporally based model that categorizes team constructs. This framework builds upon previous research on team processes (Brannick et al., 1992; Fleishman & Zaccaro, 1992; Hackman & Oldham, 1980; Jehn, 1995; Simons & Peterson, 2000). The team process taxonomy was designed to help researchers conceptualize the scope and boundaries of team processes, and to provide guidance on how to measure them effectively. The theoretical framework and taxonomy outlined by Marks et al. (2001) is most suitable for the current study because the team assessment being used for data collection was designed to measure several team processes outlined by Marks and colleagues (2001).

Marks and colleagues (2001) proposed a hierarchical structure in their team taxonomy. There are three superordinate categories including (1) transition phase

processes, (2) action phase processes, and (3) interpersonal processes in which the ten process dimensions are nested. This structure is based on Marks and colleagues' argument that some processes are more likely to take place during times of transition, whilst other processes are more likely to take place during times of activity, and interpersonal processes are expected to take place throughout both transition and action phases. The ten process dimensions, which are applicable to teams across all contexts, refer to general activities that can be performed on a spectrum from very well to very poorly. The taxonomy will be explained in further detail below.

## Transition Phase Processes

Transition phases are times when teams prioritize evaluation of previous activities or planning of future tasks (or both) to direct their achievement of a team goal (Marks et al., 2001). Considering the temporal nature of the taxonomy, transition processes occur before, or in between, team performance episodes. When time is set aside for analysis, assessment, and future direction (e.g., staff meetings, after-action reviews), processes including mission analysis, goal specification, strategy formulation and planning often take place. These are the three primary processes within the transition process phase dimension.

**Mission analysis.** Mission analysis involves comprehending and assessing the team's assigned task, which includes identifying its primary responsibilities, considering the environmental conditions in which it operates, and taking stock of the team's available resources for carrying out the mission (Marks et al., 2001). This process of understanding within the given performance context takes place as team members

interpret their roles within the boundaries of various constraints (e.g., time, resources, team abilities) and verbally discuss to ensure consensus of the team's objectives and goals. An example of when mission analysis is likely to occur would be during an initial strategic planning committee meeting where members are devising a plan to implement a new training intervention.

Mission analysis integrates backward evaluation and forward visioning (Marks et al., 2001). The retrospective aspect involves evaluating past performance and analyzing the reasons behind both successful and unsuccessful outcomes. Previous research has demonstrated that teams that gain a deeper understanding of the underlying factors contributing to their past performance are better equipped to prepare for future endeavors (Blickensderfer et al., 1998). On the other hand, the forward-looking aspect of mission analysis focuses on how the team interprets its future responsibilities in the context of ongoing developments. Teams that neglect to conduct comprehensive mission analyses may find themselves ill-prepared to adapt to changing circumstances or may be forced into a purely reactive mode of operation (Marks et al., 2001).

**Goal specification.** Goal specification is the process that teams undergo to develop overarching mission goals and subgoals that specify what and how much must be completed by a certain time and the quality criteria (Marks et al., 2001). For example, a course project team might determine the overall goal for their final deliverable (e.g., presentation, prototype) at the end of the semester. Then the team may identify subgoals, such as completing half of the project requirements by the midterm and holding a review

session two weeks before submitting the final product, to ensure they successfully meet their project deadline.

Goals function as the standard against which team members' perceptions of current or anticipated situations are compared, ultimately influencing many processes (Austin & Vancouver, 1996). The process of goal specification is important for teams because it ensures that there is a shared understanding of the team's purpose. Ideally, this procedure aligns with the timing of mission analysis and strategy formulation during the transition phase.

**Strategy formulation.** Strategy formulation refers to "the development of alternative courses of action for mission accomplishment" (Marks et al., 2001, p. 365). This entails making decisions about how team members will carry out their missions, talking about expectations, communicating information about tasks, setting priorities, assigning roles, and communicating plans to the entire team (Hackman & Oldham, 1980; Stout et al., 1999). A project planning committee holding a sequence of meetings to determine the most appropriate and efficient actions to take for the realization of the organization's vision and objectives is an example of implementing strategy formulation.

The consideration of internal and external constraints, including team resources, member skills, time restrictions, and the dynamic character of the environment is necessary for good strategy development. The resulting strategies include details on member roles and responsibilities, the sequence and timing of actions, and the best way to carry out task-related activities (Marks et al., 2001). Formulating a detailed plan for executing a team's underlying objectives and overall goal helps provide clear

expectations regarding roles and responsibilities. Communication of tasks and plans as a part of strategy formulation further enhances team functioning. Teams benefit from engaging in this team process.

#### Action Phase Processes

Action phases are episodes when teams engage in behaviors to accomplish their goals (Marks et al., 2001). Transition processes set the stage for action phases, although teams often pursue multiple goals, necessitating the engagement in transition and action processes simultaneously to manage various requirements (Mathieu et al., 2020). Identified by Marks and colleagues (2001), the four main processes that occur during action phases are monitoring progress toward goals, systems monitoring, team monitoring and backup behavior, and coordination.

Monitoring progress toward goals. Tracking progress toward mission accomplishment, assessing system information to determine what needs to be accomplished to attain goals, and providing feedback on the goal achievement status to the team are behaviors that reflect the action process of monitoring progress toward goals (Marks et al., 2001). The real time assessment of discrepancies between current progress and goals serves as a self-regulation for teams and provides opportunities for course correction when necessary. For example, a sales team will keep track of their quarterly sales to determine if they need to adjust their strategies to meet their yearly goal. Monitoring goal progression is beneficial to teams because, if done well, it curates communication among team members and assists the achievement of team objectives.

**Systems monitoring.** Systems monitoring refers to "tracking team resources and environmental conditions as they relate to mission accomplishment" (Marks et al. 2001, p. 367). The action process involves internal and external systems monitoring. Internal systems monitoring entails tracking team resources (e.g., personnel, equipment, information) whereas external monitoring involves tracking relevant environmental factors such as new events or weather patterns (Marks et al., 2001). Advances in technology have allowed teams that work in dynamic environments (e.g., hospitals) to continually monitor systems. Even teams that operate in less dynamic environments can engage in systems monitoring by holding weekly project meetings to review resource allocations or assess any potential external constraints that could interfere with project completion.

**Team monitoring and backup behavior.** Team monitoring and backup behavior is conceptualized as helping teammates complete their tasks. Assisting team members can be executed by verbally coaching or giving a teammate feedback, by supporting a teammate behaviorally while they carry out actions, or by taking on and finishing a task for a teammate (Marks et al., 2001). This process dimension includes asking for assistance from team members when needed, giving feedback, and providing task-related support. Team monitoring is mainly a cognitive function that occurs when team members watch their teammates' behaviors and look for mistakes or inconsistencies in their performance.

Backup behavior is the response to a team member's recognition of another team member's need for assistance and involves providing suggestive verbal or behavioral

feedback to help get them back on track with their performance (Dickinson & McIntyre, 1997). For instance, during an expedition, a crew of astronauts will monitor one another's behavior to identify and compensate for any critical oversight that could jeopardize the team's safety. Monitoring teammates and providing backup is critical for teams to avoid being susceptible to a single shortcoming (similar to the notion of only being as strong as your weakest link).

**Coordination.** Coordination activities are defined as the process of orchestrating the sequence and timing of interdependent actions (Marks et al., 2001). More specifically, coordination refers to the management of synchronous and/or simultaneous actions and entails the sharing of information and mutual adjustment of action (Brannick et al., 1993) to match the pace and sequencing of team member contributions with the achievement of goals (Marks et al., 2001). Students working interdependently on a team project to complete all project requirements (e.g., paper, presentation) by the deadline provides an example of coordination activities. More specifically, team members could gather all project-relevant information and compile it in a shared document or folder (i.e., Google drive). Then, they could divide the materials and delegate a certain number of presentation slides for each team member to complete. Coordination occurs during both transition and action phases. To avoid communication breakdowns and operating out of sync, teams should emphasize their coordination process by sharing all pertinent information and making necessary adjustments to properly pace team member contributions.

#### Interpersonal Phase Processes

Interpersonal processes represent processes teams utilize to manage interpersonal relationships. Within the team process taxonomy, these processes are conflict management, motivation/confidence building, and affect management. Marks and colleagues (2001) noted that interpersonal processes occur during both transition and action phases and usually provide the foundation for the effectiveness of other processes.

**Conflict management.** Operating as a team provides the interpersonal context for conflict to occur and subsequent attempts for management of conflict situations (Jehn, 1995). Conflict management is divided into two main types: preemptive conflict management and reactive conflict management (Marks et al., 2001). Resolving conflict through preemptive conflict management requires creating conditions to prevent, control, or guide team conflict prior to it occurring, whereas reactive conflict management entails working through various disagreements (e.g., task, process, interpersonal) among team members (Marks et al., 2001). Essentially, conflict management pertains to how teams handle issues that arise or have the potential to arise. Examples of conflict management include using a team contract or charter (Mathieu & Rapp, 2009) that specifies how team members agree to handle difficult situations (preemptive) and compromising on approaches to accomplishing the task and demonstrating a willingness to accept differences of opinions (reactive).

**Motivating/Confidence building.** Encouraging team members to improve or maintain their performance involves implementing motivating and confidence-building strategies that create and preserve a sense of collective confidence, drive, and task-

oriented cohesion. Within a team, motivating/confidence building involves communication of beliefs about team ability, competence on specific tasks, and feedback (Marks et al., 2001). A popular example of this process is a coach's pre-game pep talk, delivered to instill confidence in team members and motivate them to perform strongly against their opponent. Building confidence and generating motivation can enhance interpersonal working relationships and performance, helping teams attain their goals (Driskell et al., 2018; Rapp et al., 2014).

Affect management. Affect management refers to the regulation of team members' emotions. Research has examined the impact of team affect on team members' experiences (George, 1990) and team effectiveness (Kozlowski & Ilgen, 2006). Emotion regulation techniques might include efforts to reduce tension, manage members' levels of frustration, increase team morale and cohesiveness, and offer empathy (Marks et al., 2001). Marks and colleagues (2001) considered additional forms of affect management to include team activities such as joking or complaining, as long as these activities are carried out in a way that builds cohesion or breaks tension. For teams to continue to operate effectively throughout mission accomplishment, it is important to effectively manage team members' emotions. Successful affect management can help teams avoid the negative consequences of ineffective affect management like wasted time or performance issues (Marks et al., 2001).

# Summary of Taxonomy

Marks and colleagues' (2001) advanced a theory and framework to guide research focused on team processes. Ten process dimensions were classified as transition, action,

and interpersonal processes. These processes occur (often simultaneously or overlapping) during different phases throughout the duration of group work. Transition processes include mission analysis, goal specification, and strategy formulation. Monitoring progress toward goals, systems monitoring, team monitoring and backup, and coordination are considered action processes. Interpersonal processes include conflict management, motivation and confidence building, and affect management. Their framework and process taxonomy were intended to challenge the traditional ways of conceptualizing and measuring team effectiveness. Additionally, the taxonomy was designed to serve as a guide for process measurement and a basis for practical application for teams.

The team process taxonomy can be used to inform researchers' development of studies designed to measure teamwork processes (Marks et al., 2001). Transition and action processes, such as goal specification and strategy formulation, should be measured when predicting performance quality and efficiency (Marks et al., 2001). Coordination and team monitoring and backup behavior are important action processes to capture when evaluating team tasks with high member interdependency. Mission analysis and systems monitoring are vital in complex and dynamic environments. Interpersonal processes, such as conflict and affect management, influence team cohesion and, consequently, team longevity and satisfaction (Marks et al., 2001). Thus, researchers interested in predicting team affective outcomes should assess interpersonal processes and examine the relationships between interpersonal processes and affective outcomes.

Previous research has utilized this taxonomy and provided additional insight to the differential effects of team processes on team outcomes (e.g., Ilgen et al., 2005; Kozlowski & Bell, 2003; Kozlowski & Ilgen, 2006; LePine et al., 2008). Such findings have guided researchers' recommendations for designing studies examining processes that impact team functioning (e.g., Mathieu et al., 2017; Shuffler et al., 2018). Measuring all components of team performance, including affective outcomes (Shuffler et al., 2018), is necessary for advancing team research and achieving a comprehensive understanding of the relationships between team processes and outcomes. Another important consideration for research examining team processes is the time-dependent nature of interactions (Cronin et al., 2011; Mathieu et al., 2017). Despite the challenges associated with assessing both performance and affective components of team effectiveness and accounting for the dynamic aspect of team processes, it is necessary to incorporate these elements into studies to advance theory and practice.

## Team measures assessed in present study

The team process taxonomy did not include an exhaustive list of team processes (an intentional design as the authors wanted to avoid a list too lengthy to provide value); however, other research has identified additional factors relevant to team performance and affective outcomes which are included in the current study. Team research would further benefit from studies examining the degree to which team outcomes are impacted by specific processes. In addition to gaining more insight into how transition, action, and interpersonal processes affect team outcomes, the present study advanced team research

by evaluating other mechanisms that influence team dynamics to provide a more nuanced understanding of teamwork.

There are several transition, action, and interpersonal processes measured in the present study. The team assessment also included measures for two additional team processes: role clarity and cooperative conflict management; two team emergent states: trust and psychological safety; as well as two team outcome measures: team potency and team satisfaction. The processes, states, and outcomes that were examined are detailed in the following sections.

#### **Team Processes**

#### Strategy formulation

Strategy formulation refers to a transition process concerning the development of overall strategies that guide team efforts, including the sequencing of planned work elements, evaluation of processes, and formulation of contingency plans (Marks et al., 2001). Empirical evidence suggests that initial planning behaviors are positively correlated with improved team performance (Stout et al., 1999). Planning before a mission, during a mission, or both can improve team effectiveness (DeChurch & Haas, 2008). The team can, for instance, establish objectives, foster an open environment, communicate information about the demands of the task (e.g., talking about the repercussions of mistakes and going over prepared material), and make sure that everyone on the team understands their respective roles and duties (Blickensderfer et al., 1997). Teams can also talk about pertinent environmental features and limitations (e.g., how a heavy workload impacts performance, how the team will handle this limitation,

and how they will handle unforeseen events), assign priorities to tasks, identify the information that each member of the team has access to and that is held by specific individuals, and talk about expectations, including how they will support one another or self-correct (Stout et al., 1999).

#### *Role clarity*

Role clarity is the existence of well-defined and understood roles within a team. The collective understanding and clarity of roles is demonstrated through the establishment and maintenance of delineated responsibilities, goals, expectations, and relative authority of each role within the team. The presence of role-relevant information (Lyons, 1971), role clarity, has long been an area of interest amongst scholars. Rooted in organizational role theory (Kahn et al., 1964), the lack of pertinent information provided to an individual, role ambiguity (the converse of role clarity), will likely increase the individual's role dissatisfaction and anxiety, ultimately hindering performance effectiveness.

A lack of clarity regarding responsibilities and expectations can have negative ramifications for team members and the entire team. According to Rizzo et al. (1970), when workers are unaware of role expectations, they could be reluctant to take action, exhibit a lack of self-determination, and believe they have little power to influence the organization's objectives. Uncertain role expectations have been linked to an increase in employee work withdrawal behaviors, such as absenteeism and turnover (Katz et al., 1964). Another detrimental aspect of unclear objectives and role responsibilities is failure
to achieve high levels of performance, even by the most competent and driven workers (Yukl, 2010).

#### *Team monitoring and backup*

Team monitoring and backup behavior refers to a shared awareness of the relative strengths and weaknesses of each team member. This process involves all team members monitoring standards of work and offering support to each other as needed. The provision of task support to a team member who is overloaded, also known as backup behavior, has been shown to have positive effects on team performance (Porter et al., 2003). Once a team member recognizes another team member's need for assistance, they can help get them get back on track with their performance by providing suggestive verbal or behavioral feedback (Dickinson & McIntyre, 1997). The monitoring of team performance and provision of backup is a helpful action process that teams often engage in throughout the duration of a team project.

The discretionary provision of task-related effort to a team member that is experiencing difficulties is intended to assist that individual with achieving their role defined responsibility (Porter et al., 2003). Effective monitoring of teammates' execution of their roles and engaging in backup behavior can contribute to the team's overall goal attainment. In highly interdependent teams, team monitoring serves as a tool to help members manage their own behavior jointly with that of their teammates as well as a means of identifying mistakes or misjudgments made by team members (Marks & Panzer, 2004). The utility of this team process has arguably led to the attention it has received in team research.

Several studies have examined this team process to assess its effects on team performance outcomes. Marks and Panzer (2004) explored the associations between team performance and methods for coordination, feedback, and monitoring. Their findings showed support for the hypotheses that monitoring improves coordination and that coordination and feedback mechanisms fully regulate the association between monitoring behavior and more distal team performance. Teams that monitored member performance and execution seemed better equipped to gauge their teammates' pace of completing tasks and modify their own timing, accordingly, making it easier for them to finish their interdependent tasks on time. Marks and Panzer (2004) noted a shift toward processbased organizations that requires organizations to focus on teamwork skills as a means of gaining competitive advantages. The changing nature of work and the results of their study, taken together, highlight a need to prepare individuals to work effectively in team settings, including training team processes such as team monitoring.

## Monitoring progress towards goals

The consistent evaluation of progress and accomplishment of team goals by team members is considered monitoring goal progression. This action process involves using precisely defined metrics to monitor and assess the team's progress, pacing, and accomplishment of goals. Identifying gaps and inadequacies and giving team members performance feedback are examples of tasks that reflect the team process of monitoring progress toward goals (Marks et al., 2001). Through these exercises, teams can evaluate differences between objectives and accomplishments and adjust their actions as needed.

## *Coordination*

Coordination is considered the dynamic arranging of efforts to achieve a greater goal or function (Gorman, 2014). Effective coordination provides a smooth workflow between team members. This team process involves an integration of each team member's work efforts and an efficient way of re-aligning in response to any error or challenge. Coordinating as a team allows groups to perform tasks and accomplish goals that individuals could not complete alone. Coordination is another team process categorized as an action process within Marks and colleagues' (2001) taxonomy of team processes.

# Cooperative conflict management

Cooperative conflict management is an approach to conflict and incompatibilities in a manner that seeks out win-win solutions. According to O'Neill et al. (2018), this process "occurs when individual team members see their own goals as being positively related to the goals of other team members" (p. 8180). Teams that see conflict as a shared issue in need of discussion and resolution have faith that other team members would reciprocate and cooperate to find mutually beneficial solutions (Alper et al., 2000). These expectations encourage the full exchange of opposing viewpoints and ideas, which are then combined to provide practical, win-win solutions. When teams embrace a mutually compatible perspective, conflict is viewed as an opportunity to learn from each other and understand the problem at a deeper level (O'Neill et al., 2019).

Tjosvold's (1998) review of cooperation and competition theory approach to conflict outlines the opposing approaches to managing conflict in organizations and

provides insight to overcoming the associated practical challenges. Additionally, Tjosvold (1998) highlights the benefits of taking a cooperative approach to conflict management. Conflict exists in relationships where people have both cooperative and competitive interests. Research has indicated that teams characterized by highly cooperative goals tended to openly discuss opposing opinions (Alper & Tjosvold, 1993). Similarly, Tjosvold (1998) noted that cooperative goals prompt people's willingness to integrate opposing viewpoints and ultimately reach an agreement. Engaging in cooperative conflict management yields positive outcomes including high quality decisions, strengthened teamwork, and improved performance (Tjosvold, 1998). Cooperative conflict management allows teams to proceed past situations that could potentially hinder goal achievement.

## **Team Emergent States**

According to Marks et al. (2001) team emergent states refer to dynamic team characteristics that fluctuate as a function of inputs, processes, outcomes, and context. Ilgen et al. (2005) describes emergent states as constructs that arise over the course of a team's existence and influence team outcomes. Rapp et al.'s (2020) review of team emergent state research provides a taxonomy of team emergent states (TES) that extends Marks et al.'s (2001) conceptualization of TES as cognitive, affective, and motivational. Rapp and colleagues' taxonomy categorizes over 50 TES constructs into seven categories: (1) cognitive, (2) affective, (3) motivational, (4) cognitive/affective, (5) cognitive/motivational, (6) affective/motivational, and (7) cognitive/affective/motivational. Within Rapp et al.'s (2020) taxonomy, trust is considered a cognitive TES, which concerns members' beliefs and thoughts, and psychological safety is deemed an affective TES, which pertains to members feelings, attitudes, and emotions.

Throughout years of team research there has been an entanglement of both the conceptualization and measurement of team processes and emergent states (e.g., DeChurch et al., 2013; Marks et al., 2001). The inadequate articulation of these constructs has resulted in a noticeable blurring between team processes and resulting emergent states (Marks et al., 2001). Subsequently, measurements of these explanatory mechanisms have inaccurately assessed the actual process or emergent state that is taking place or developing. For example, researchers may attempt to measure an emergent state such as team conflict (members' shared judgments of the level of disagreement over tasks or relationships; DeChurch et al., 2013), but actually use items that measure members' interactions aimed at working through task and interpersonal disagreements, which is a team conflict process (Ilgen et al., 2005). The need for research that clearly defines processes and states and appropriately measures these concepts has been recognized (Cronin et al., 2011; Driskell et al., 2018; Fyhn et al., 2023; Marks et al., 2001; Rapp et al., 2021). To contribute to the necessary disentanglement and respond to calls for additional research focusing on the unique relationships between team processes, emergent states, and team outcomes (Driskell et al., 2018; Fyhn et al., 2023; Rapp et al. 2021), the current study emphasizes the distinction between team processes and team emergent states and tests a model to understand how these distinct predictors are related to team outcomes. The constructs within the current study that are team emergent states

include trust and psychological safety. A review of these emergent states is provided in the following sections.

#### Trust

Trust has been defined as "a psychological state that manifests itself in the behaviors towards others, is based on the expectations made upon behaviors of these others, and on the perceived motives and intentions in situations entailing risk for the relationship with those others" (Costa et al., 2001, p. 228). Similarly, trust is described by O'Neill and colleagues (2018) as the extent to which team members perceive and have confidence in the integrity, reliability, and overall trustworthiness of members within their work group. The degree to which a team member trusts another directly affects that team member's actions (Pearce et al., 1992). Therefore, cultivating trust is beneficial to interpersonal and working relationships amongst team members.

As a critical component of social relations (Pearce et al., 1992), trust has been a popular topic in organizational science research. There are several meta-analyses examining trust and job performance (e.g., Breuer et al., 2016; Colquitt et al., 2007; de Jong et al., 2016; Morrissette & Kisamore, 2020). Research spanning more than four decades has conclusively demonstrated the importance of trust in teams to the effective operation of work relationships (Costa et al., 2017). Mayer and colleagues (1995) developed an integrative model of trust that advanced the understanding of trust in organizational studies. Mayer et al.'s (1995) model of trust incorporated the dynamics of trust accounting for characteristics of both the trustee and trustor and differentiated trust from its contributing factors. Continuing the research on the role of trust in organizational

settings, Dirks and Ferrin (2001) developed an alternative model (to Mayer's "main effect" model) with trust as a moderator. They explored a moderation model to discover how trust could operate in an organization by moderating the effects of other determinants on work related outcomes (e.g., attitudes, perceptions, behaviors, performance). Dirks and Ferrin's (2001) framework provided researchers with guidance to appropriately design future studies to more accurately measure trust and the effects of trust in various work-place contexts. Their framework supplied managers with insight into when trust is likely to function according to both the main effect model and moderation model.

Extensive research on trust has led to the identification of several factors that impact trust at the team level. These factors include team composition, task structure, degree of virtuality, team leadership, and team climate (Costa et al., 2017). Within crossfunctional teams, the development of trust can be hindered by conflicting goals, unshared information, or perceived differences in professional backgrounds (Jassawalla & Sashittal, 1999). A negative relationship between demographic diversity and team trust and perceptions of trustworthiness has been found within the literature examining team composition and its effect on teams (Chowdhurry, 2005; Williams, 2006; Zolin et al., 2004). Additionally, trust at the team level is influenced by existing relationships between team members and the strength and configuration of these connections (Costa et al., 2017). Teams with strong ties have been shown to successfully achieve their goals and exhibit higher levels of trust compared to teams with weak relationships (Balkundia & Harrison, 2006). Team climate impacts team trust as demonstrated by research showing that climates characterized by interpersonal trust and mutual respect allow members to feel comfortable expressing their thoughts and opinions (Edmonson, 1999).

## Psychological safety

Psychological safety facilitates a team's pursuit of appropriate actions to achieve teamwork (Edmonson, 1999). Team psychological safety refers to a shared belief that a team is safe for interpersonal risk taking and a shared sense of confidence that team members will not be punished or embarrassed for sharing ideas (Edmonson, 1999). The concept of team psychological safety includes interpersonal trust but goes beyond it by referring to a team climate, distinguished by mutual respect and interpersonal trust, in which team members can comfortably be themselves (Edmonson, 1999). When team relationships are characterized by trust and respect, team members are more likely to believe they will receive the benefit of the doubt from other members (Kahn, 1990). Supported by qualitative and quantitative data, Edmondson's research (1996; 1999; 2002; 2003) suggests that team psychological safety existed at the group level of analysis. Edmondson's research illustrated the value of examining team psychological safety, in addition to other constructs typically examined in team research, to better understand team functioning.

Psychological safety research has centered on the premise that it encourages people to willingly contribute their thoughts and efforts toward a common goal (Edmondson & Lei, 2014). Edmondson and Lei (2014) reviewed conceptual and empirical research focused on psychological safety, which included works examining its nature, contributing factors, and implications for individuals, teams, and organizations.

Their review revealed that few studies have examined the dynamics of psychological safety over time, therefore, they concluded additional longitudinal research will improve assessment of its causes, effects, and changes.

The present study responds to Edmondson and Lei's (2014) call for more longitudinal research examining psychological safety. The authors also noted that future research focusing on psychological safety would benefit from mixed methods approaches, using qualitative and quantitative data to reveal more information about experiences of psychological safety and its causal relationships. Studies utilizing qualitative methods have contributed to conceptualizing how and why psychological safety develops and influences work outcomes by providing detailed explanations (Newman et al., 2017). The present study examined qualitative data by applying topic modeling to determine if any team constructs, such as team psychological safety, emerged from the qualitative feedback. The present investigation aims to contribute to the intersection of psychological safety research and teams research to better understand how psychological safety influences group outcomes and demonstrate the importance of its role for individuals, teams, and organizations.

## **Team Outcomes**

Teams are evaluated on a variety of outcomes to assess their effectiveness and success. Described by Mathieu et al. (2008) as by-products and results of team activity, outcomes include performance and members' affective reactions (e.g., satisfaction). Throughout decades of team research, researchers have explored a plethora of determinants of team performance to better understand mechanisms that enhance team

performance as well as factors contributing to team failures. Commonly researched team outcomes include task performance (Costa, 2003; Espinosa et al., 2015; Harrison et al., 2002; Troth et al., 2012), satisfaction (DeChurch & Marks, 2001; De Dreu & Weingart, 2003; Johnson & Avolio, 2019; Standifer et al., 2012), effectiveness (Cohen & Bailey, 1997; McGrath, 1964), cohesion (Carless & De Paola, 2000; Kozlowski & Chao, 2012; Zaccaro, 1991), and creativity (Anderson et al., 2014; Mathieu et al., 2008; Mueller & Cronin, 2009; Paulus et al., 2012).

Understanding how teams function and perform effectively will allow researchers to provide research-based recommendations to enhance team functioning and support the practical importance of teamwork within organizations. To gain a comprehensive understanding of the relationships and dynamics between team processes and emergent states and team outcomes, the current investigation assesses the relationships between perceptions of the aforementioned predictors and team potency and team satisfaction. By exploring these relationships and examining the effects of each determinant, the current study aimed to provide nuanced insight into key drivers of team potency and satisfaction.

#### CHAPTER THREE

# HYPOTHESIZED LINKS OF TEAM PROCESSES AND EMERGENT STATES TO TEAM OUTCOMES

The overarching goals of the present study were to examine the relationships between the perception of different types of team processes and perceptions of team outcomes, and to examine the relationships between perceptions of team processes and emergent states and perceptions of team outcomes. The present study focused on team potency and team satisfaction as outcomes. The goal of this chapter is to develop hypotheses about specific links between team processes and team outcomes, and those between team emergent states and team outcomes. The hypothesized relationships between various transition, action, and interpersonal team processes and each outcome are outlined in the following sections. Additionally, the proposed relationships between team emergent states and both outcomes, respectively, are discussed.

# **Team Potency**

Group potency refers to "the collective belief of group members that the group can be effective" (Shea & Guzzo, 1987, p. 26). Research uses group potency and team potency interchangeably. Within the current manuscript, group potency is used when referring to a study that used that terminology, otherwise the concept is referred to as team potency. A concept related but not identical to group potency (Guzzo et al., 1993) is collective efficacy. Collective efficacy refers to an individual's belief about a group's effectiveness and does not represent a belief shared by others. Therefore, the distinction lies within the attribution; collective efficacy is an attribute of individuals while group

potency is an attribute of groups (Guzzo et al., 1993). Although potency and collective efficacy are similar constructs, there is empirical evidence that supports that they are distinct and meaningful predictors of team performance (Gully et al., 2002; Ilgen et al., 2005; Lee et al., 2002).

Extant research has provided evidence indicating that group potency and performance are positively correlated (Durham et al. 1997; Gully et al., 2002; Guzzo et al., 1993; Hecht et al., 2002; Jung & Sosik, 1999; Jung et al., 2002; Mulvey & Klein, 1998; Shea & Guzzo, 1987). More specifically, previous findings indicate that potency is positively related to individuals' self-ratings of effectiveness, leaders' assessments of team performance, and productivity (Campion et al., 1993, 1996). Notably, potency was the only significant predictor of all outcome measures in both of Campion's studies. Further evidence for the positive relationship between potency and performance is provided by Silver and Bufanio's (1996) examination of the relationships between group potency, goals, and task performance among student groups. Their findings demonstrated that group potency was positively and significantly related to task performance. Hecht et al. (2002) explored the relationships between group goal commitment, group member ability, group potency, and performance. Hecht et al.'s (2002) results supported their hypothesis that group potency would contribute to predicted performance above and beyond group member ability.

Several studies examined the connection between potency-related constructs and team effectiveness using a more nuanced methodology. In a reciprocal model that was evaluated by Jung and Sosik (1999), potency, outcome expectation, group heterogeneity,

and inclination for group work were proposed as distinct predictors of group performance. Results indicated that perceptions of group potency and preference for group work were the strongest predictors for performance both at time one and time two. Additionally, the findings demonstrated that group performance predicted perceptions of group potency, outcome expectation, group heterogeneity, and preference for group work at time one. The significance of this research was that the main findings indicated a special reciprocal relationship between potency and team performance. In another assessment of reciprocity, Sivasubramaniam et al. (2002) found a reciprocal relationship between transformational leadership and potency.

Research has also examined the antecedents and consequences of team potency. Akgun and colleagues (2007) assessed trust, past experiences of project team members, empowerment of team members, and goal clarity as antecedents of team potency and speed-to-market, development cost, and market success of software as consequences. The results of a partial least squares (PLS) analysis showed a positive association between team potency and intrateam trust, team experience, and team empowerment; there was not a significant association between goal clarity and team potency. In terms of team potency and software development-related outcomes, the results indicated team potency is positively related to speed-to-market, low software development cost, and market success.

Hu and Liden (2011) examined goal clarity, process clarity, and servant leadership as antecedents of team potency and team effectiveness (as indicated by team performance and team organizational citizenship behaviors (OCB)). Hu and Liden (2011)

hypothesized that goal and process clarity would be positively associated with team potency; their findings supported these hypothesized relationships. Results demonstrated that goal clarity, process clarity, and servant leadership were all significantly related to team potency. Team potency was hypothesized to partially mediate the relationships between goal clarity and process clarity and team performance and team OCB (team effectiveness). The findings provided evidence that there was stronger support for full mediation rather than the hypothesized partial mediation. Thus, team potency fully mediated the relationships between goal clarity and process clarity, and team effectiveness (Hu & Liden, 2011).

An extensive amount of research focused on teams has been dedicated to determining the factors that influence team effectiveness and discovering ways to improve team performance. Based on the extant literature focused on team potency, one can conclude that team potency is an important mechanism to examine when assessing team dynamics. To extend the current understanding of the role of team potency, the current study examined the relationships between perceptions of team processes, including strategy formulation, role clarity, team monitoring and backup, monitoring goal progression, and coordination, and perceptions of team potency.

# Strategy formulation and team potency

Strategy formulation stems from McGrath's (1984) conceptualization of a performance plan which refers to a series of actions linked by time and function that will lead to a specific outcome or goal if properly executed by the group. Strategy formulation is the establishment of general strategies that lead team efforts, such as the sequencing of

scheduled task items, process evaluation, and contingency planning (Marks et al., 2001). A team can establish objectives, foster an open environment, communicate information about the demands of the task (e.g., discussing the ramifications of mistakes and going over prepared material), and ensure that everyone on the team understands their respective roles and duties by participating in strategy formulation (Stout et al., 1999).

Previous research has examined planning (Blickensderfer et al., 1997; DeChurch & Haas, 2008; Hackman, 1987; Stout et al., 1999; Zaccaro et al., 1995), shared mental models (Cannon-Bowers et al., 1993; Mathieu et al., 2010; Orasanu, 1990; Stout et al., 1999), and communication (Kilner & Sheppard, 2010; Matusovich et al., 2012; Mohanty & Mohanty, 2018) to understand coordinated performance in teams. In addition to these processes related to strategy formulation the three sub-dimensions of strategyformulation: deliberate planning, contingency planning, and reactive strategy adjustment (Marks et al., 2001), have received attention in team research. Initial intentional planning is considered an important team activity (Cannon-Bowers & Bowers, 2011). Stout and colleagues' (1999) empirical findings showed that initial planning behaviors are linked to enhanced team performance. Planning that occurs while teams are executing tasks is an important determinant of team performance (Gevers et al., 2001; Weingart, 1992). Evidence supporting team planning behaviors as an important predictor of situational awareness amongst teams was reported by Patrick et al. (2006). In an examination of teams of firefighters, McClennan et al. (2006) found a positive connection between planning and team effectiveness. DeChurch and Haas (2008) examined each type of planning delineated by Marks et al. (2001), and their results demonstrated predictive

value for each type at different stages throughout a team's performance. According to their results, the strongest predictor of team effectiveness was reactive adjustment followed by contingency planning and deliberate planning (DeChurch & Haas, 2008).

Despite extant literature examining the sub-dimensions of strategy formulation, there is less research focusing specifically on the overarching process of strategy formulation and its effects on team outcomes such as team potency. To advance research on teamwork, the proposed study examined the relationship between perceptions of strategy formulation among team members and team potency perceptions. Engaging in strategy formulation helps clarify the team's goals, priorities, and direction. When team members actively participate in developing strategies to achieve shared objectives, they gain a clearer understanding of the team's purpose and how their individual efforts contribute to that purpose. This sense of direction and purpose instills confidence and motivation and can lead to greater perceptions of potency within the team. Through the process of discussing and developing strategies together, team members develop a shared understanding of the team's priorities and how they can best leverage their collective strengths to achieve success. The positive impacts of successful strategy formulation can reinforce perceptions of potency within a team as they work together toward shared objectives. I expect that team members' perceptions of strategy formulation will be positively related to their perceptions of team potency. Therefore, I propose the following:

*Hypothesis 1a*: Team members' shared perceptions of their team's *strategy formulation* will be positively related to their perceptions of team potency.

## *Role clarity and team potency*

Team research has assessed role clarity to determine how this process affects team performance outcomes. Evidence provided by research on small groups has indicated that role clarity is crucial for the efficient operation of workgroups (Bray & Brawley, 2002). To properly carry out their work and organize group activities, group members must have a clear understanding of these role expectations. Members of a group may undervalue their ability to accomplish the goals of the group if they are unclear about their roles (Bandura, 1997), which would result in subpar collective performance (Bray & Brawley, 2002). Thus, previous research suggests there are several negative implications for workgroups to operate with unclear role expectations.

On the opposite end of the spectrum, research focusing on clear and collective understanding of expectations, responsibilities, and goals has demonstrated the benefits of role clarity. Higher levels of role clarity have been found to be directly related to higher levels of perceived organizational effectiveness, job satisfaction, and personal influence (Posner & Butterfield, 1978). Higher levels of role clarity have also been shown to be related to higher levels of role efficacy (Bray & Brawley, 2002). In their examination of the potential relationships between role clarity, role efficacy, and role performance effectiveness, Bray and Brawley (2002) found that groups with higher role clarity had significantly higher role efficacy compared to those with lower role clarity, and role clarity moderated role efficacy's effect on role performance effectiveness. Hassan (2013) examined role clarification's effect on perceived role clarity, work satisfaction, and turnover rates in a government agency's workgroups. The results showed that role clarification was significantly and positively related to role clarity. Similarly, Hassan's (2013) findings provided evidence for a positive relationship between role clarity perceptions and work satisfaction and a negative relationship between role clarity perceptions and turnover rates. In addition to finding support for role clarity's direct effect on related outcomes, the results indicated that role clarity perceptions partially mediated the relationship between role clarification and work satisfaction and fully mediated the effect of role clarification on turnover rates.

Lynn and Kalay (2015) assessed the influence of vision and role clarity on team performance to contribute to the lack of studies examining the direct impact of role clarity on team performance. They pointed out that several scholars (e.g., Beauchamp & Bray, 2001; Jehn & Bendersky, 2003; Puck & Pregernig, 2014) have suggested further research is needed to explore the effect of role clarity on team performance. Additionally, they highlighted Deeter-Schmelz's (1997) assertion that role clarity is a key structural variable that impacts team dynamics, and it should be investigated in future research. Lynn and Kalay (2015) found that vision clarity was positively related to team performance; however, they did not find a significant relationship between role clarity and performance. It is clear that a better understanding of the role which role clarity plays in team dynamics is needed.

Role clarity within a team is essential for its effective functioning, encompassing well-defined and understood responsibilities, goals, expectations, and authority for each team member. The absence of such clarity can lead to adverse consequences, including reluctance to take action, decreased self-determination, and a minute sense of influence

among team members. Conversely, a clear understanding of roles has been associated with positive outcomes, including higher perceived organizational effectiveness, job satisfaction, and personal influence. Despite previous research suggesting the significance of this mechanism, the degree to which role clarity affects team performance is uncertain due to the dearth of research focusing on its direct and indirect effects. Previous studies, such as Lynn and Kalay (2015), have explored related factors like vision clarity but found inconclusive evidence regarding the direct relationship between role clarity and team performance. The current study contributes to this gap by investigating the link between perceptions of role clarity and team potency, shedding light on how role clarity within teams influences overall team performance. When team members have a clear understanding of their roles and responsibilities within the team, they know what is expected of them and how their contributions contribute to the team's overall goals. Role clarity helps to reduce ambiguity and uncertainty, allowing team members to focus their efforts more effectively. As a result, team members are more likely to feel confident in their ability to fulfill their roles, leading to greater perceptions of potency within the team. Therefore, I propose that perceptions of role clarity will be positively associated with team potency.

*Hypothesis 1b*: Team members' shared perceptions of their team's *role clarity* will be positively related to their perceptions of team potency.

## *Team monitoring and backup behavior and team potency*

Monitoring involves keeping track of team members' progress, identifying potential problems, and proactively addressing issues as they arise. Backup behavior

involves providing support and assistance to team members when needed.

Acknowledging the increasing reliance on teams and teamwork within organizations, Porter et al. (2003) argued that backup behavior is an important yet often ignored team process and serves as a fruitful avenue for future empirical research. According to Porter and colleagues (2003), the current organizational trend toward developing team-based structures relies on the concept of dynamic readjustment afforded by team monitoring and backup behavior. In their exploration of backup behaviors in teams, they assessed the role of team members' personalities and the need for backup behavior. The findings indicated that team performance was higher when team members provided backup behavior to team members who were experiencing a heavy workload. Porter and colleagues (2003) also provided empirical evidence that backup behavior has positive effects on team performance. To build upon previous examinations of backup behavior, they argue there is a need for additional research on team monitoring and backup to provide insight into when this process occurs (or does not) in work teams.

Research focused on team processes has focused on the role of monitoring and backup behavior. Previous findings suggest that team monitoring and backup may potentially serve as a moderator or mediator in team process and outcome models, revealing that its role (as currently understood) is rather complex. In a recent examination of the role of backup behavior, Kude et al. (2019) found that backup behavior moderates the negative effect of task novelty on team performance. Budianto et al. (2020) tested a model examining the moderating effects of team monitoring on the relationships between team psychological safety and team performance and team learning and team

performance. Their findings provide evidence that team monitoring moderates the relationship between team learning and team performance, however, the interaction between team monitoring and team psychological safety was not related to team performance. The researchers speculated that the stage of team development (Tuckman, 1965) could contribute to the explanation for the insignificant interaction effect.

Schmidt and colleagues (2014) developed a model examining the effects of agile practices (e.g., code reviewing) on shared mental models and backup behavior in software development teams. Focusing on shared mental models and backup behavior as determinants of team performance, Schmidt et al.'s (2014) findings suggest that teams using agile quality assurance techniques (e.g., pair programming, code reviews) have more shared mental models and are more inclined to demonstrate backup behavior. They also discovered that when teams encounter a highly complex task, backup behavior improves the team's performance. These examinations of backup behavior highlight the need for a more nuanced understanding of this team process, as well as the notion that additional factors, such as task novelty and complexity and team development stage, influence the degree to which teams demonstrate monitoring and backup behavior. The critical consideration of external factors when determining the complex dynamics of team processes will be implemented during the interpretation of the current study's results.

The extant literature examining team monitoring and backup behavior has demonstrated the value of this team process, however, future research is needed to better understand not only *how* team monitoring and backup affects team outcomes but also *when* this process is impacting teamwork. Teams that engage in effective monitoring and

backup behavior are better equipped to coordinate their actions and adapt to changing circumstances. These behaviors help ensure that tasks are completed efficiently and that team members feel supported, which can contribute to a sense of potency or confidence in the team's ability to accomplish its goals. Confidence in each other's abilities can contribute to greater potency perceptions within the team. When team members know that their colleagues are monitoring their progress and ready to provide assistance, if necessary, they feel more secure and confident in their abilities to perform effectively. Similarly, effective monitoring and backup behavior can help reduce fear of failure and can increase confidence in the team's ability to overcome challenges. As a result, team members are more likely to perceive the team as potent and capable of achieving its objectives. Thus, I proposed that team members' perceptions of their team's ability to effectively monitor and backup would be positively associated with the team members' perceptions of team potency.

*Hypothesis 1c*: Team members' shared perceptions of their team's *team monitoring and backup* will be positively related to their perceptions of team potency.

# Monitoring progress towards goals and team potency

There are several benefits to monitoring goal progression during team projects. Research assessing the role of monitoring goals has demonstrated that engaging in this process increases team performance in terms of focusing on searching for information, planning, and properly allocating resources to team tasks (Bandura & Locke, 2003; Lindsley et al., 1995). Austin and Vancouver's (1996) foundational research on goal constructs (e.g., structure, process, and content) highlights the essential need for an

evaluation of progress to assist with making decisions centered around goal revision, strategy change, or goal attainment. Through a self-regulatory lens, Rapp and colleagues (2014) examined the relationship between team goal monitoring and teams' perceptions of their ability to perform tasks. They found that goal monitoring moderates the curvilinear relationship between team efficacy and team performance, such that teams engaged in higher levels of goal monitoring had better performance outcomes compared to those with lower levels of goal monitoring. Monitoring goal progression is critical for teams to emphasize throughout their mission because it allows for identification of performance gaps, assists with synchronization of contributions, and allows for adjustments to any potential deviation from optimal performance plans (Rapp et al., 2014).

The monitoring of goal progression has been found to be a key mechanism through which teams can enhance team performance outcomes (Rapp et al., 2014). Actively engaging in team goal monitoring makes team members cognizant of their fellow team members' assessments of team performance and individual contributions toward team goals. This mutual understanding should contribute to group members' accountability and promote progress toward goal attainment. Therefore, I propose that teams' perceptions of their ability to emphasize the monitoring of goal progression are associated with their perceptions of performance conceptualized as team potency. When teams actively monitor their progress towards goals, they can identify areas where improvements could be needed and are aware of their ability to execute tasks effectively. As team members monitor progress and experience success, their perceptions of potency

are reinforced, as they see tangible evidence of the team's capability to achieve its objectives.

*Hypothesis 1d*: Team members' shared perceptions of their team's *monitoring of goal progression* will be positively related to their perceptions of team potency.

## *Coordination and team potency*

Due to the criticality of coordination in teamwork, this process has been a focal topic with team research. Gorman (2014) examined dynamic and shared-knowledge approaches to team coordination to highlight two central issues and provide suggestions for a general theory of team coordination. Gorman (2014) addressed the question of whether causal mechanisms exist within or between individuals and the issue of the level of analysis at which effects of team coordination are observed. This review provided insight into the dynamic approach, which focuses on how real-time coordination processes shape both individual and team performance, and the traditional sharedknowledge approach, which focuses on internal mental processes and states serving as the foundation for coordination effects. The dynamic perspective suggests that the causal basis of coordination stems from the real-time coordination process unfolding between individuals (Gorman, 2014). In other words, the dynamic approach supports the notion that team coordination happens during the process of team interactions. This review contributed to coordination research by proposing a general theory of team coordination, involving an integration of shared intention and knowledge from team members (representing the shared-knowledge perspective) and dynamics and contextual constraints

(representing the dynamics perspective), plus consideration of coordinative linkages' structural influence on thought and action when people work interdependently.

Within the context of multi-team research and design projects, Hoegl et al. (2004) explored the coordination within and between teams. Investigating how processes at the team and inter-team level impacted team performance, they assessed 39 teams working on a three-year long product development project. The results indicated that team member ratings of inter-team coordination, project commitment, and teamwork quality, which were measured at the end of the concept phase (month 12), were significantly correlated with project managers' ratings of overall team performance at the end of the project (month 36). Notably, the results showed weaker correlations between the same process variables captured at the end of the design phase (month 24) and team performance measured at the end of the project. A key takeaway from Hoegl et al.'s (2004) study was that, in the early stages of a team project, collaboration within and between teams had a significant effect on later team performance. Thus, the process of coordination within a team is important for researchers to include in examinations of team processes and their related effects on team performance.

Coordination is a constant requirement in team projects. Hoegl et al.'s (2004) results demonstrated that early-stage collaborative processes, such as inter-team coordination, possess predictive properties in terms of end of project ratings of overall team performance. Building on the notion set forth by Hoegl et al.'s (2004) work, the current study examined the perceptions of coordination and the relationship between coordination and team potency. Measuring team members' perceptions of coordination

has the potential to predict perceptions of team performance at a later phase of the project. Research has shown that team coordination dynamics are linked to team effectiveness and can be manipulated to improve team performance (Gorman et al., 2010). In summary, empirical evidence has shown that team coordination contributes to team performance.

Effective coordination ensures that tasks are executed efficiently and in a timely manner. When team members can collaborate and synchronize their efforts, they are better able to achieve their goals. This efficient task execution fosters a sense of accomplishment among team members, leading to positive perceptions of potency within the team. Teams that work together to accomplish tasks and collaborate effectively are likely to be perceived by their members as more potent and capable of attaining their goals. Drawing conclusions based on extant coordination research, the following hypothesis is proposed:

*Hypothesis 1e*: Team members' shared perceptions of their team's *coordination* will be positively related to their perception of team potency.

# **Team Satisfaction**

Researchers that are primarily concerned with predicting team effectiveness, as defined by satisfaction or longevity (Hackman & Morris, 1975), ought to assess interpersonal dynamics (Marks et al., 2001). Previous research has emphasized the importance of considering team members' attitudes and feelings towards the team (e.g., team satisfaction) when studying team effectiveness (Marks et al., 2001; Mathieu et al., 2008; Shuffler et al., 2018). The importance of team satisfaction is evident from the

extensive amount of research on this topic (e.g., Johnson & Avolio, 2019; LePine et al., 2008; Mathieu et al., 2008; Standifer et al., 2012). Research has shown that team satisfaction is linked to conflict management (e.g., Behfar et al., 2008; De Dreu & Weingart, 2003), trust (Braun et al., 2013; Dirks & Ferrin, 2001), and psychological safety (Johnson & Avolio, 2019). Interpersonal processes have a significant likelihood of influencing team cohesion over time, which is a key determinant of team longevity and satisfaction (Marks et al., 2001). According to Mathieu and colleagues (2008), when assessing team effectiveness, it is essential for researchers to account for team members' feelings towards the team. Team members' satisfaction with their team encompasses team members' affect toward the team as well as feelings regarding team viability (Johnson & Avolio, 2019). Team members' feelings and thoughts about working with the same team in the future are influenced by their team satisfaction (Van der Vegt et al., 2001). Therefore, it is reasonable to conclude that team satisfaction is an important aspect of team dynamics.

A review of team satisfaction literature in its entirety falls outside the scope of the proposed study; however, a review of team satisfaction literature narrowed to focus on team constructs examined within the current study is warranted. To highlight previous findings of relationships between these team constructs and team satisfaction and build support for the propositions within the current study, the following sections will review several notable studies.

#### Conflict management and team satisfaction

Conflict management has been examined in relation to various team outcomes including team performance and satisfaction (e.g., De Dreu & Wingart, 2003) and cohesion, commitment, and decision making (De Wit et al., 2012). Due to conflict causing stress, animosity, and diverting team members' attention from the task at hand, it has been proposed that conflict hinders team performance and lowers satisfaction (De Dreu & Wingart, 2003). Previous research suggests by reestablishing justice, process effectiveness, resource efficiency, working relationships, and group satisfaction, a *process* for conflict management can help mitigate the negative effects of all types of conflicts (Thomas, 1992). Therefore, cooperative conflict management could serve to improve team outcomes (e.g., satisfaction).

Behfar et al. (2003) examined team-level conflict resolution strategies to gain insight into their effects on team performance and team satisfaction. The results of this study indicated that teams which developed a focus on finding an appropriate, albeit not always equal, way for all team members to contribute efforts given their respective constraints were able to achieve performance goals and had high member satisfaction. These teams were able to understand compromises and trade-offs made by individuals and the team as a whole when planning how to deal with issues that could potentially arise, which allowed them to cooperatively manage or prevent destructive conflicts. In contrast, Behfar et al. (2003) found that teams on the other end of the spectrum (i.e., teams with low performance and low satisfaction) applied an "ad hoc approach to managing conflict" (p. 184). This type of approach is characterized by the lack of role

clarity, lack of identification and correction of root causes of problems, and absence of a coherent conflict management strategy. Behfar et al. (2003) concluded that conflict resolution strategies influence team viability. Their study provided a more nuanced understanding of the variations of performance and satisfaction tradeoffs that are associated with conflict resolution strategies.

To address an apparent disconnect in team conflict literature between theory and empirical evidence that suggests conflict is beneficial or detrimental, De Dreu and Weingart (2003) conducted a meta-analysis examining the validity of the opposing perspectives of the relationship between conflict and team performance. One perspective (information processing) supports the notion that conflict interferes with team performance and team member satisfaction and is similarly related to task and relationship conflict. The opposing perspective suggests that task and relationship conflict both interfere with team member satisfaction, but only relationship conflict negatively affects team performance whereas task conflict has potentially beneficial effects on team performance. The results of their meta-analysis showed a significant negative correlation between relationship conflict and team performance as well as a significant negative correlation between task conflict and team performance. There was a weaker association between task conflict and team member satisfaction compared to relationship conflict, however, both appeared to negatively impact satisfaction. In summary, De Dreu and Weingart's (2003) findings illustrated that both types of conflict were equally disruptive to team performance, supporting the information processing perspective, and both types of conflict harmed team member satisfaction.

Another example of empirical evidence supporting the relationship between conflict management and team performance and satisfaction is provided by Dimas and Lourenco's (2015) two field studies. Dimas and Lourenco (2015) noted that conflict management has garnered little empirical attention. They examined conflict management and analyzed its role as a moderator of the relationship between conflict and two criteria of team effectiveness (team performance and team member satisfaction). Recognizing the benefit of taking a multi-level perspective (De Wit et al., 2012) to better understand the implications of team processes effects on team effectiveness, Dimas and Lourenco (2015) examined the direct and indirect effects of conflict and conflict management on team performance (group-level) and team members' satisfaction (individual-level). Their rationale for examining the direct effects of conflict management is based on notion that the way people interact to resolve conflict is a more proximal mechanism for explaining team outcomes and affective reactions compared to conflict states (e.g., task conflict) (DeChurch et al., 2013) and the proposition that evaluating a process that a team can control is necessary when aiming to improve team functioning in organizations (Mello & Delise, 2015). Dimas and Lourenco's (2015) findings suggested that group performance and team members' satisfaction can be increased by reducing conflict within a group and equipping team members with the necessary abilities to manage conflict cooperatively.

In summary, previous research indicates that taking a cooperative approach to resolving conflict allows teams to manage a variety of types of conflict (e.g., relationship, task) in a way that is beneficial to the group (Tjosvold, 1991). Behfar et al. (2003) illustrated the critical role of conflict resolution in teams and provided support for a

connection between conflict management style and team outcomes. De Dreu and Weingart (2003) concluded that conflict was harmful to team satisfaction based on their meta-analytic review of conflict, team performance, and team satisfaction. Dimas and Lourenco (2015) argued that the use of an integrative approach, where cooperative goals are emphasized, could lead to the development of stronger interpersonal relationships and a more comprehensive understanding of team members and existing conflicts, ultimately leading to teams with higher productivity and satisfaction.

## *Cooperative conflict management*

Conflict management capabilities have been argued to be especially important for self-managed work teams due in part to the fact they have to resolve issues related to work roles, production procedures, different personalities, and ideas about the best way to accomplish tasks (Alper et al., 2000). Research has shown that cooperative conflict management is linked to perceptions of efficacy in resolving conflict and overall team performance (Tjosvold et al., 2000). The utility of managing conflict cooperatively is demonstrated through problem solving, task accomplishment, and strengthened relationships (Tjosvold et al., 2014).

Research has shown that collectivistic processes, namely cooperating and openness, are positively related to affective outcomes (DeChurch et al., 2013). Additionally, high quality resolutions and strong relationships are outcomes of emphasizing cooperative goals and pursuing mutually beneficial solutions in situations where conflict has arisen (Tjosvold et al., 2014). Teams with a cooperative orientation toward conflict hold discussions with the intention of resolving differences and work to

determine a solution that satisfies both parties (Elgoibar et al., 2017). The utilization of this type of approach to conflict is likely to lead to higher levels of team satisfaction. The benefits of emphasizing a cooperative approach to conflict, as previously highlighted, include quality resolutions and relationships which positively influence team satisfaction.

Additionally, high quality resolutions and strong relationships are outcomes of emphasizing cooperative goals and pursuing mutually beneficial solutions in situations where conflict has arisen (Tjosvold et al., 2014). Teams with a cooperative orientation toward conflict hold discussions with the intention of resolving differences and work to determine a solution that satisfies both parties (Elgoibar et al., 2017). The utilization of this type of approach to conflict is likely to lead to higher levels of team satisfaction. The major benefits of emphasizing a cooperative approach to conflict, as previously highlighted, include quality resolutions and relationships which positively influence team satisfaction.

Within the context of the present study, cooperative conflict management is a mutually beneficial strategy for approaching task-related or relationship-related problems or potentially destructive issues that arise within the team (Alper et al., 2000). The current study examined perceptions of cooperative conflict management and the effects on perceived team satisfaction. The perceptions of utilizing a win-win approach to managing conflict is hypothesized to positively contribute to perceptions of team satisfaction. When team members work together to address differences constructively, rather than allowing conflicts to escalate and undermine relationships or progress, teams can adapt and overcome challenges. This can reinforce perceptions of potency as team

members see the team as capable of resolving conflicts. By engaging in constructive dialogue and considering opposing perspectives to problem solve, teams can work together to achieve their goals. In congruence with what is known about emphasizing a cooperative approach to conflict, I propose that perceptions of cooperative conflict management will be positively related to perceptions of team satisfaction.

*Hypothesis 2a*: Team members' shared perceptions of their team's *cooperative conflict management* will be positively related to their perceptions of team satisfaction.

#### Trust and team satisfaction

Trust between team members is essential to their ability to collaborate effectively (Grossman et al., 2017). Trust involves team members to willingly be vulnerable and rely on other team members to perform actions or tasks based on the expectation that they will execute the action that is important to other team members (Mayer et al., 1995). Once all members of a team share this expectation, it emerges as team trust. Thus, team trust is an emergent state and refers to a shared psychological state between team members based on positive expectations of one another (Fulmer & Gelfand, 2012).

The significance of trust and related perceptions had been demonstrated through research highlighting its influence on relationships and behaviors in teams. Several internal factors (e.g., personality, cultural background) and external factors (e.g., life experiences, education) influence people's propensity to trust others (Mayer et al., 1995). Within work teams, van der Werff and Buckley (2017) showed individuals' tendency to trust contributes to the explanation for varying levels of trust within newly formed teams. Kramer et al. (2001) argued that knowledge level and sense of belonging to the team

shape people's perceptions about who is trustworthy and beliefs regarding the consequences of trust, which in turn influences how they behave. Narrowing in on the development of trustworthiness perceptions between team members, Levin and colleagues (2006) found that demographic similarity, trustworthy behaviors, and shared perspective contributed to these perceptions.

In the workplace, interpersonal and group dynamics are being emphasized more, and trust is considered one of the essential components of effective teamwork (Costa et al., 2001; O'Neill et al., 2019). In an examination of trust and perceived task performance, team satisfaction, relationship commitment, and stress, Costa et al. (2001) demonstrated the importance of trust for teams in organizations. They found a positive relationship between trust and perceived task performance, team satisfaction, and relationship commitment. Their results also indicated that trust is negatively related to stress. de Jong et al.'s (2016) meta-analytic review of trust among team members (referred to as intrateam trust), illustrated growing scholarly interest in intrateam trust and team performance. Within the literature there appears to be a greater focus on the effects of trust between team members and team performance outcomes compared to the effects on team affective outcomes. The present study sought to contribute to research examining the effects of trust within teams by examining the effect of perceptions of team trust on perceived team satisfaction.

In an examination of trust and perceived task performance, team satisfaction, relationship commitment, and stress, Costa et al. (2001) demonstrated the importance of trust for teams in organizations. They found a positive relationship between trust and

perceived task performance, team satisfaction, and relationship commitment. Their results also indicated that trust is negatively related to stress. Building on previous research, Costa (2003) explored the relationship of trust with team performance, team satisfaction and other attitudinal variables. Data from 112 teams, with a minimum of three members, were collected via a questionnaire and analyzed using structural equation modeling (SEM). The results showed that high work team trust is an indicator of high perceptions of task performance, team satisfaction, and attitudinal commitment, and low continuance commitment. These findings supported the hypothesized positive relationship between high levels of trust between team members and team satisfaction, and, more generally, the importance of trust in team functioning.

Breuer et al. (2016) extended trust research by conducting a meta-analysis on trust and team effectiveness. Their meta-analytic review included a total of 54 independent samples, including student project teams and professional teams, from the 564 studies obtained. Their results showed a strong, positive relationship between team trust and team-related attitudes including satisfaction with the team, commitment to the team, perceived team cohesion, and effort intentions toward the team. They also demonstrated a significant positive relationship of team trust with team satisfaction and perceived team cohesion. Their results highlight not only the positive relationship between team trust and team satisfaction across numerous studies, but also the integral role of trust in teamwork.

Trust is a relevant component of teamwork (Dirks & Ferrin, 2001). Chen (2014) highlighted Carson's (2007) findings about the benefits of a positive team environment in student projects (i.e., promotion of shared leadership) and suggested that this type of

supportive environment can foster interactions among team members that promote emergent states such as trust. Trust is important within student engineering teams because there are multiple components of the course project and team members rely on one another to successfully complete the project in its entirety. In other words, one member of the team would not be able to complete the project alone, therefore team members must trust that other team members will perform their assigned tasks. Although teams are working together to complete the project, there will be instances when individuals are working on different tasks and will have to make personal judgment calls. Trust among team members allows for these judgment calls to be made on an individual basis without consulting the entire group for every minor decision (e.g., what image to include on a presentation slide). Therefore, to achieve a better understanding of team dynamics it is important to examine how trust among team members affects team outcomes such as team satisfaction. The current proposal aimed to contribute to both teams and trust literature by examining perceptions of trust in teams and the relation to perceived team satisfaction.

Trust is a key component of effective collaboration within a team. When team members trust each other's capabilities and intentions, they are more likely to communicate openly and work together to achieve their goals. Similarly, when trust and belief in the team's collective abilities exists, team members are more likely to invest time and effort into the group project. Trust fosters a sense of a supportive environment and contributes to a more enjoyable and satisfying team experience. Thus, I propose
perceptions of trust within a team will be positively related to the perceptions of team satisfaction.

*Hypothesis 2b*: Team members' shared perceptions of their team's *trust* will be positively related to their perceptions of team satisfaction.

## Psychological safety and team satisfaction

Psychological safety refers to the shared belief within a team that members can express themselves without fear of reprisal, ridicule, or judgment (Edmondson, 1999). In today's organizational dynamics landscape, the concept of psychological safety has emerged as a critical component impacting team dynamics and satisfaction. Psychological safety as a team construct has been considered to have a significant influence on team performance (Bergmann & Schaeppi, 2016; Budianto et al., 2020). Teamwork involves complex interactions and collaboration between team members, and psychological safety can help navigate these interactions between team members and integrate individuals' unique skills to improve team performance (Budianto et al., 2020). As the reliance on teams and teamwork continues to grow within organizations (Kozlowski & Ilgen, 2006), there is an increasing need to foster supportive working environments and positive culture that encourage team contributions (Nembhard & Edmondson, 2006). Therefore, it is critical to continue expanding knowledge of team psychological safety and its role in teamwork through empirical research.

Newman et al.'s (2017) meta-analysis of psychological safety identified 44 empirical studies examining the antecedents of psychological safety and 62 that focused on the outcomes. Of the 44 studies examining the antecedents, almost all (38) examined psychological safety's mediating role to determine how various supportive behaviors and individual or team characteristics influenced numerous workplace outcomes at the individual, team, and organizational level (Newman et al., 2017). The review revealed that research examining factors that interact with psychological safety is limited, but that work examining the moderating effects of psychological safety is growing. The systematic review of psychological safety literature included studies examining psychological safety and its effect on several outcomes within the overarching categories of organizational outcomes, team outcomes, work behaviors, and work attitudes. However, regarding team outcomes, there appeared to be a greater emphasis on performance and learning outcomes rather than affective outcomes in the literature.

Although research has examined the antecedents and outcomes of team psychological safety, Schulte et al. (2012) noted that research has focused less on the "dynamic mechanisms through which individuals' perceptions of their team's psychological safety develop and influence team members' interactions" (p. 566). To respond to this scarcity, Schulte and colleagues (2012) developed and tested a conceptual framework to examine six reciprocal mechanisms through which individual team members' perceptions of their teams and team members' social network ties may coevolve. Schulte et al.'s (2012) findings highlight the reciprocal and intricate ways in which team members' interpersonal relationships and their perceptions of their team coevolve over time, forming the team's network structure and shaping psychological safety climate. Their framework and findings indicate that a team's network structure and psychological safety climate emerge through a bottom-up process that is fueled by the individual-level mechanisms of prospective action and assimilation as well as the network-specific effects of homophily, reaction, and retrospective sensemaking. This study illustrated the complexity of the various intertwining mechanisms that influence the evolution of team members' perceptions of psychological safety. Schulte et al. (2012) concluded team members are more likely to ask their colleagues for assistance and view them as friends and less likely to report having tough interactions with them if they perceive their team to be psychologically safe. Thus, this research highlights the importance of teams' perceptions of psychological safety when assessing antecedents of team effectiveness.

Johnson and Avolio (2019) examined initial perceptions of teams' psychological safety interaction with team relationship conflict's trajectory to explore the effects on team identification and satisfaction. Based on their expectations of high levels of psychological safety leading to team members' comfortability sharing information and reduced uncertainty about working with their team, Johnson and Avolio (2019) proposed that high levels of psychological safety would result in higher levels of team identification and ultimately team satisfaction. They discovered that subsequent levels of an individual's team identification were influenced not only by their initial perceptions of the psychological safety of their team during team formation, but also by the interaction between those initial perceptions and the trajectory of team relationship conflict. Team members who first perceived higher levels of psychological safety on the team but then experienced an increasing trajectory of relationship conflict also had lower levels of

identification and evaluated their satisfaction with the team lower almost nine months later.

Team members' perceptions of their team, including perceptions of team psychological safety, reflect and influence their members' willingness to seek advice or support from their teammates (Schulte et al., 2012). Team members are more likely to view other teammates as friends and less likely to have strained relationships when they perceive their team as being psychologically safe (Schulte et al., 2012). A psychologically safe environment allows individuals to willingly engage in their team's performance rather than disengaging or having to focus efforts on defending themselves (Kahn, 1990).

The current study investigates the relationship between psychological safety and team satisfaction, aiming to unravel the extent to which a culture of openness and trust influences the overall well-being and contentment of team members. Because team members are influenced by the same structural factors and because these perceptions arise from important shared experiences, perceptions of psychological safety, like other similar beliefs, should converge in a team (Edmondson, 1999). When team members witness situations where attention and appreciation are shown in response to discussion of their own and others' mistakes, for instance, most team members will conclude that making a mistake does not result in embarrassment or rejection. Therefore, I propose team members' perceptions of their team's psychological safety will be positively related to their perceptions of team satisfaction.

*Hypothesis 2c*: Team members' shared perceptions of their team's *psychological safety* will be positively related to their perceptions of team satisfaction.

#### **Team Emergent States**

As previously mentioned, the present study intended to emphasize the distinction between team processes and emergent states. One of the distinctions between team processes and team emergent states pertains to their development over time. Team processes are essential for coordinating tasks and planning activities in the short term. Throughout the duration of a project, team processes help ensure team members work together and efficiently complete tasks. Team emergent states, such as cohesion, develop gradually as team members work together, interact, and build relationships. States emerge from interactions and elemental aspects such as team composition. They are persistent and influence how teams operate over time. Functioning as a team-level property, emergent states can also influence how team members collaborate and interact at the individual level, thus influencing team processes as part of a recursive feedback loop. In summary, while team processes refer to the actions and interactions that occur within a team, team emergent states emphasize the collective perceptions, attitudes, and behaviors that emerge from those interactions. Both aspects are essential for understanding and fostering effective teamwork.

Additionally, both team processes and team emergent states shape team dynamics and team outcomes. Team processes have been linked to team performance, satisfaction, and effectiveness (e.g., DeChurch & Haas, 2008; Porter et al., 2003). Positive team emergent states, such as high cohesion, have been associated with improved team

performance, increased satisfaction, and high levels of innovation and creativity (e.g., Costa et al., 2001; DeChurch & Mesmer-Magnus, 2010; Gully et al., 2002). However, it is important to assess the temporal aspect of the respective influence of team processes and emergent states on team outcomes. The present study examines the relationships between various team processes and emergent states and perceived team satisfaction and team potency at two timepoints to assess the magnitude of the effect of both at different stages of a team project. Based on how team processes impact initial team efforts (e.g., planning, coordinating), I hypothesize that perceptions of team processes will have a greater effect on perceived team satisfaction and team potency at the midpoint (time one) compared to perceptions of team emergent states. I expect that team members will not have had enough time to experience or witness the emergence of trust and psychological safety, therefore their perceptions of these emergent states will not have as strong of an effect.

*Hypothesis 3*: Team members' shared perceptions of their team's processes (strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, and cooperative conflict management) at time one will have a stronger relationship with perceptions of team satisfaction (a) and team potency (b) at time one than perceptions of team emergent states (psych safety and trust) at time one.

In contrast, I also hypothesize that compared to time two perceptions of team processes, perceptions of team emergent states at time two will have a greater effect on perceived team satisfaction and potency. Once teams have had more time to collaborate and interact, the team-level states will have had time to emerge, and subsequently the

perceptions of these states will have a greater influence on perceived team satisfaction and potency. Team processes can and likely will still influence these outcomes towards the end of the project, however, they might not have as significant of an effect compared to the effect they had at the beginning of the project when team processes were critical to kicking off team efforts. For example, if trust has emerged as a result of individual level interactions, and especially if there is a high level of trust among the team, then the perceptions of this emergent state will likely influence several aspects of team functioning (e.g. communication), and ultimately have a greater effect on perceived team satisfaction and team potency compared to perceptions of team processes. Similarly, over time team level psychological safety perceptions permeate team members' interactions and can influence team members' perceptions of the team's ability to achieve their goals and their perceptions of an enjoyable or satisfying experience. Thus, I propose the following hypothesis:

*Hypothesis 4*: Compared to team members' perceptions of team processes (strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, and cooperative conflict management) at time two, team members' perceptions of team emergent states (psych safety and trust) at time two will have a stronger relationship with their perceptions of team satisfaction (H4a) and team potency (H4b) at time two.

In addition to the differences between team processes and emergent states, the effects of emergent states can differ over time. Fyhn and colleagues (2023) reviewed longitudinal studies on team emergent states to identify key takeaways from research that examined team emergent states over time. Their review revealed that team trust is a team

emergent state that has been studied extensively, but the temporal dynamics of trust have only been assessed in a few longitudinal studies (Fry et al., 2017). After reviewing papers that examined various aspects of trust, Fyhn et al. (2023) suggested that "team trust may not only emerge over time but also relate to different variables at different time points" (p. 4). Therefore, there could be a stronger relationship between perceptions of trust and perceived team satisfaction and potency at the end of a project compared to the relationships at the midpoint of the project.

Team members' perceptions also vary at different stages of team projects. Jung and Sosik (2003) found that working together over time and receiving feedback impacted team members' perceptions such that team members' perceptions of collective efficacy were more homogenous later in the project. Research has shown that collective perceptions can emerge from positive or negative interactions among team members that subsequently have varying impacts on team functioning (DeRue et al., 2010). The present study examined perceptions of trust and psychological safety at two different times during a semester-long project and assessed the relationship between perceived trust and psychological safety and perceived team satisfaction and team potency. Since emergent states require time to emerge within teams and there are fluctuations in these states that can impact team operations, I expect that perceptions of team emergent states at the end of the project (time two) will have a greater effect on perceived team satisfaction and potency at the conclusion of the project compared to perceptions of these states at the midpoint (time one). Therefore, I propose the following:

*Hypothesis 5*: Compared to perceptions of team emergent states (psych safety and trust) at time one, the perceptions of team emergent states at time two will have a greater effect on team members' perceptions of team satisfaction (H5a) and team potency (H5b) at time two.

### CHAPTER FOUR

## METHODOLOGY

# Overview

This chapter provides details of how this study was conducted. Data were collected as part of an ongoing effort to transform the civil engineering department at a large southeastern university. Advancing the program and focusing on student success and professional development involved exploring ways to improve the course curriculum. Therefore, assessments were administered within second-, third-, and fourth-year civil engineering courses. The primary researcher compiled data from all the assessments to be used for analysis. Both quantitative and qualitative data from the assessments were analyzed.

## **Participants and Procedure**

The participants were 403 students in a civil engineering program at a large southeastern university. Participants were assigned to groups composed of three to five members. There was a total of 114 teams. Students were required to complete the class project for a course grade; completion of both assessments was a part of the team project requirements. The participant population consisted of 25.8% females, 73.9% males, and less than 1% non-binary. The age breakdown of the participant population is as follows: .5% were 18 years old, 8.7% were 19, 13.9% were 20, 36.5% were 21, 20.8% were 22, 4.96% were 23, 6.5% were 24, 4.7% were 25, 1.99% were 26, .5% were 27,28, and 31. The participant population consisted of 12.9% Sophomores, 29.0% Juniors, and 58% Seniors.

The team health assessments were administered in sophomore, junior, and senior courses, with the total number of courses equaling 15. There were group projects for each course (e.g., junior design course project; senior capstone course project). Groups within the same class completed the same project. Students were assigned to project teams by the course instructor. Previous research has called for clarity regarding the association between temporal constructs and team outcomes measured at different time points throughout a project timeline (Bartel & Milliken, 2004). The notion that team processes and states need time to develop within teams was taken into consideration (Standifer et al., 2012), thus these mechanisms were measured twice over the course of the semester, at the midpoint and at the end of the semester. Researchers have encouraged future research to employ time-based designs (LePine et al., 2008) and collecting measures at appropriate times (Marks et al., 2001). Additionally, previous research suggests richer insight into team dynamics is achieved through longitudinal studies (Fyhn et al., 2023). The same assessment was administered at both time points. Students were required to answer each assessment question and provide qualitative feedback within the assessment.

## **ITP Metrics Team Dynamics Assessment**

The ITP team dynamics assessment provides a wealth of information about students' perceptions of various team processes. This assessment utilizes the CARE model, which defines effective team health and dynamics in terms of Communication, Adaptability, Relationships, and Education (O'Neill et al., 2018). The CARE model was developed by O'Neill and colleagues (2018). Model development took place in three stages with the first involving an extensive literature review on teamwork in business,

education, and psychology, the second involving a construct classification workshop to organize the constructs according to content and themes, and the final stage consisting of efforts focused on the creative identification of a concise and interesting framework that could be used for pedagogical purposes (O'Neill et al, 2020).

The team dynamic assessment utilizes multi-item facet-level scales borrowed directly from previous publications that provided reliability and validity evidence. These are utilized to ensure the accuracy, reliability, and validity of the items (O'Neill et al., 2020). O'Neill and colleagues (2020) aimed to shorten the CARE assessment and increase its accuracy by conducting reliability and exploratory factor analyses. Once the items for what is henceforth called the Bare CARE assessment were identified, the researchers evaluated the psychometric quality and content of the revised, substantially shorter version of the CARE assessment. O'Neill et al. (2020) demonstrated the adequacy of the Bare CARE assessment through comparisons between the original and Bare CARE scales that indicated very similar intra-class correlations (ICCs), concurrent validities that reliably captured content validity and nearly identical criterion validities. The team dynamics assessments administered in the present study consisted of the Bare CARE assessment.

There are data quality checks within the team dynamics assessment. For example, following the role clarity items there is an item that reads "Please respond 'Strongly Agree' to this question". Data collected from respondents who did not correctly answer one of the data quality assurance items were removed prior to data analysis.

### Measures

All measures from the team dynamics assessment were collected at the midterm (time 1) and at the end of the semester (time 2). The assessment includes the following prompt before each set of questions: "Please report your agreement with the following statements regarding your team". The following measures were used in the present study.

*Strategy formulation* was measured with three items from Mathieu et al.'s (2020) team process scale. Specifically, three out of five items from the 'strategy formulation and planning' subscale of Mathieu et al.'s (2020) team process scale were used. An example of a strategy formulation item is, "We develop an overall strategy to guide our team activities". Respondents rated the items on a 5-point scale ranging from (1) "strongly disagree" to (5) "strongly agree".

*Role clarity* was measured with three items adapted from Rizzo et al. (1970). The items are adapted to read "we" rather than "I" to reflect team dynamics. For example, the original scale item "I know exactly what is expected of me" is adapted within this assessment to be "We know exactly what is expected of each other". Another example of a role clarity item includes, "There are clear, planned goals and objectives for each of our roles". Respondents rated the items on a 5-point scale ranging from (1) "strongly disagree" to (5) "strongly agree".

*Team monitoring and backup* was measured with three items from Mathieu et al.'s (2020) team process scale. An example of a team monitoring and backup item includes, "We help a team member who is overwhelmed with tasks". Respondents rated the items on a 5-point scale ranging from (1) "strongly disagree" to (5) "strongly agree".

*Goal progression* was measured with three items from Mathieu et al.'s (2020) team process scale. An example of an item measuring goal progression includes, "Regularly monitor how well we are meeting our team goals". Respondents rated the items on a 5-point scale ranging from (1) "strongly disagree" to (5) "strongly agree".

*Coordination* was measured with three items from Mathieu et al.'s (2020) team process scale. An example of an item measuring coordination includes, "Our team smoothly integrates our work efforts". Respondents rated the items on a 5-point scale ranging from (1) "strongly disagree" to (5) "strongly agree".

*Cooperative conflict management* was measured using three items from the five cooperative approach items within Tjosvold's (1985) cooperative approach to conflict scale. An example of a cooperative conflict management item includes, "Team members encourage a 'we are in it together' attitude as they negotiate their differences". Respondents rated the items on a 5-point scale ranging from (1) "strongly disagree" to (5) "strongly agree".

*Trust* was measured using three items adapted from the trustworthy scale provided by Pearce et al. (1992). An example of an item measuring trust includes, "I can rely on those with whom I work in this group". Respondents rated the items on a 5-point scale ranging from (1) "strongly disagree" to (5) "strongly agree".

*Psychological safety* was measured using Edmonson's (1999) 7-item team psychological safety scale. An example of an item measuring psychological safety includes, "Members of this team are able to bring up problems and tough issues". Respondents rated the items on a 7-point scale ranging from (1) "very inaccurate" to (7) "very accurate". The scale range and reversed items are consistent with Edmonson's (1999) original scale.

*Team potency* was measured using four items from the potency scale provided by Guzzo et al. (1993). An example of an item measuring team potency includes, "Our team believes it can be very productive". Respondents rated the items on a 5-point scale ranging from (1) "strongly disagree" to (5) "strongly agree".

*Team satisfaction* was measured using five items from Kline's (1999) team player inventory. An example of an item measuring team satisfaction includes, "Compared with other teams I have worked on, this team works well together". Respondents rated the items on a 5-point scale ranging from (1) "strongly disagree" to (5) "strongly agree".

# Data analysis

The relationships between team processes and emergent states and team outcomes were explored using both time one and time two data. The data collected from the scale items in the ITP metrics team dynamics assessment, measuring team processes, emergent states, and team outcome variables, were analyzed quantitatively. The open text feedback comments provided by respondents were used for qualitative analyses. The quantitative and qualitative analyses are outlined in the following sections.

## **Quantitative analyses**

All statistical analyses were conducted using R and RStudio. R is a language and environment for implementing statistical techniques (R Core Team, 2024). This free software provides a variety of statistical and graphical techniques for data manipulation, calculation, and visualization. RStudio is the integrated development environment (IDE)

through which users can access R, conduct statistical analyses and produce graphics, view workspace objects, and access help files (Racine, 2012).

Team level variables were used for analyses. To calculate these total scores I averaged the scale item scores to get an individual's score on each measure (e.g., calculating the mean of the three items measuring strategy formulation), and then I used each team member's individual average and calculated the mean to obtain the team average score for each measure (e.g., team member A's strategy formulation average plus team member B's average plus team member C's average, divided by three equals the team average score for SF). Aggregation to the team-level was required before hypothesis testing. Therefore, within-group agreement was measured as a prerequisite for aggregation of team members' ratings (Biemann et al., 2012). The within-group agreement index for multiple item measures,  $r_{WG(J)}^*$ , which provides an agreement for raters mean scores on J items, was computed. Lindell and colleagues (1999) proposed this modified formula to address concerns with James et al. (1984)  $r_{WG(J)}$  formula being based on the Spearman-Brown formula which was developed for a reliability index, as well as James et al.'s recommendation of substituting 0 for negative values of  $r_{WG}$  ( LeBreton et al., 2005). According to Bliese (2022), the  $r_{WG(J)}$  is "calculated by substituting the average variance of the items in the scale into the numerator of the  $r_{WG}$ formula in lieu of using the  $r_{WG(J)}$  formula ( $r_{WG} = 1$  - Observed Group Variance/Expected Random Variance)" (p. 15). The R package 'multilevel' includes a function, rwg.j.lindell, which was used to calculate the within-group agreement for all time one and time two measures.

Based on Biemann et al.'s (2012) recommendations regarding the justification of data aggregation from a lower level (e.g., individual) to a higher level of analysis, the interrater reliability was calculated to avoid solely relying on r<sub>WG</sub>-based indices (James et al., 1984; 1993). Intraclass correlation coefficient (ICC1), the proportion of the total variance explained by the grouping structure (e.g., team), and (ICC2), the reliability of aggregated variables (i.e., team means) (Bliese et al., 2000), were calculated to demonstrate consistency of the aggregated measures (Woehr et al., 2015). The ICC1 and ICC2 were calculated for all time one and time two measures using the *mult.icc* function in the multilevel R package.

A series of multiple linear regression analyses were conducted to determine the relative significance of each predictor on the associated outcome variables of interest (team satisfaction and team potency). The first series of multiple linear regressions analyzed the relationships between perceptions of time one team processes (strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, and cooperative conflict management), time one team emergent states (trust and psychological safety), and time one team satisfaction. In the first series of multiple linear regressions strategy formulation, role clarity, team monitoring and backup, and backup, monitoring and backup, monitoring goal progression, coordination are the predictor variables and team satisfaction is the outcome variable. This multiple linear regression tested Hypothesis 3a.

The second series of multiple linear regression analyses was conducted to analyze the relationships between the same team process perceptions and team potency as proposed in Hypothesis 3b. Thus, time one perceptions of strategy formulation, role

clarity, team monitoring and backup, goal progression, coordination, cooperative conflict management, trust and psychological safety were regressed onto time one perceptions of team potency.

After the regression analyses were completed, the assumptions associated with multiple linear regressions (e.g., homoscedasticity; normality; linearity) were checked using appropriate data visualizations (e.g., Q-Q plots to assess normality). The homoscedasticity, normality, and linearity assumptions were checked using appropriate data visualizations (e.g., Q-Q plots to assess normality), and none of these assumptions were violated. VIF values for each predictor were assessed and indicated that multicollinearity was not an issue.

# **Qualitative analyses**

Topic modeling methods were leveraged to explore the conditions surrounding teamwork that influence how team processes and emergent states manifest and interact. The purpose of using a topic model, as a statistical model, is to be able to learn something about the data or assist with hypothesis formation (Blei, 2012). There are several advantages to using topic modeling, including (1) enabling the analysis of empirically derived lists of words through the automatic identification of "hidden" themes, (2) the scalability of topic models to thousands of documents without human coding or manual annotations, and (3) the ability to rate topic likeness, retrieve information, and identify the most representative documents (Banks et al., 2018).

To assist with a comprehensive understanding of this advanced statistical approach, the following narrative is provided outlining how topic modeling works

(including a few important terms). In the context of topic modeling, a *word* is an item from a vocabulary that serves as a basic unit of data. A *document* is a sequence of words, and a *corpus* is a collection of documents (Blei et al., 2003). Now that some common terminology has been reviewed, imagine that an analyst is tasked with reviewing company ABC's information technology (IT) support requests. The analyst can compile all of the IT support requests and save them in a spreadsheet. These open-ended text comments will serve as the input *documents*. Next, the analyst takes the *corpus* (collection of documents) and applies a topic model. Subsequently, the topic modeling algorithm returns a set of themes, also referred to as *topics*, pertaining to the documents. Depending on the algorithm chosen, some topic models provide the degree of relevance for each word within the topic, which allows the analyst to understand the importance of each topic within each document and within the whole collection. The resulting topics are lists of related words. For example, the output of topics the analyst receives includes four groups of words (top 5 words provided for the sake of simplicity): (1) bills, statement, account, rate, invoice; (2) uncertain, wondering, how, why, confused; (3) survey, response, opinion, criticism, assessment; and (4) objection, disapprove, negative, dislike, poor. Using subjective interpretation, the analyst creates labels for each topic: (1) Billing; (2) Questions; (3) Feedback; and (4) Complaints. Using topic modeling to analyze the large dataset of IT support requests allows the analyst to efficiently evaluate thousands of requests, uncover underlying themes within these requests, and provide easily understandable results to ABC's management team.

To complement the proposed quantitative analyses, topic modeling techniques were applied to text comments as a means of providing further insight to any questions that arose or conclusions that were drawn from quantitative results. After applying the topic model to the qualitative team data, I reported additional findings. A discussion of these findings is included in the following chapters.

### Advantages of Qualitative Methods

The value of qualitative methods is illustrated through their capability to provide detailed descriptions of complex phenomena, uncover previously hidden themes within large datasets, extract contextual information to provide greater insight into processes or incidents being measured. Qualitative methods are also useful for developing theories, conceptual frameworks, and hypotheses (Saefer, 1999). Qualitative data can be generated from interviews, observations, focus groups, and surveys. Qualitative research provides insight into the context in which the data was collected and facilitates a more comprehensive understanding of the perceptions, experiences, and processes at play (Richard, 2013). Studies utilizing qualitative methods have contributed to the nuanced understanding of various team constructs (i.e., processes, states) by providing detailed accounts of how these mechanisms develop and influence team outcomes (Newnan et al., 2017). Recent developments in areas of computer science and statistical programming have expanded and advanced researchers' use of qualitative data and related methods. These techniques that provide new avenues for qualitative research are discussed in the following sections.

It is important to draw attention to the numerous advantages of using qualitative methodology, as well as to incorporate these statistical techniques into study design to demonstrate utility. Research can be strengthened by implementing a rigorous qualitative approach and presenting empirical evidence in a manner that illustrates the dynamic relationships among the data, emerging concepts (well-specified notion explaining a phenomena of interest), and resulting theory (Gioia et al., 2012). Additionally, there is value in leveraging the advantages of qualitative approaches in conjunction with quantitative methods. Using both quantitative and qualitative methods could provide greater insight into this area of research in ways that either method alone is not able to accomplish (Creswell, 2014; Johnson & Avolio, 2019).

# Natural language processing

Natural language processing (NLP) is a branch of computer science that focuses on utilizing computational methods to learn, comprehend, and produce information in human languages (Hirschberg & Manning, 2015). According to Liddy (2001), natural language processing (NLP) comprises computational techniques for evaluating and modeling naturally occurring texts at one or more levels of linguistic analysis to achieve human-like language processing for a variety of tasks or applications. In short, NLP is a computerized approach to analyzing text. This technique originated in the 1950s at the intersection of artificial intelligence and linguistics (Nadkarni et al., 2011). After several decades of advancements, the current state of NLP reflects foundational contributions from a variety of fields including computer and information science, linguistics, mathematics, psychology, artificial intelligence, and others (Chowdhury, 2003).

NLP uses computers to understand and manipulate natural language text or speech to perform a variety of desired tasks. The objectives of computational linguistic systems (also known as NLP) can be varied. Human-human communication can be enhanced by machine translation (MT), human-machine interaction can be facilitated by conversational agents, or both humans and machines can benefit by examining and learning from the massive amount of human language content that is currently available online (Hirschberg & Manning, 2015). There are numerous NLP methods available for researchers to use as a tool for analyzing qualitative data. Given the scope and context of the current research, I will highlight the text processing technique used in this study: topic modeling.

# Topic Modeling

Topic modeling is an unsupervised machine learning technique that is designed to analyze document collections and produce accurate and coherent core themes based on the text input (Churchill & Singh, 2022). Machine learning research indicates that statistical topic modeling is becoming increasingly useful as a tool for analyzing massive, unstructured text collections (Blei, 2012; Wallach et al., 2009). Continued advancements in unsupervised machine learning paired with increased access to a continuously growing digital archive of information provide an avenue for topic modeling approaches to be applied to big data (Blei, 2012). Topic modeling has been argued as a promising approach for exploring large collections of documents to uncover meaningful thematic structure (Blei, 2012). The primary topics that are pervasive throughout a sizable and otherwise unstructured collection of documents can be found using topic model algorithms. Subsequently, topic models can arrange the collection based on the themes that were uncovered (Blei, 2012).

Topic modeling has predominantly been used to evaluate social media data, as reflected by research using twitter data (Barry et al., 2018; Paul & Dreze, 2014; Valdez et al., 2020; Zhang et al., 2022). There are a few noteworthy examples of topic model applications. Fong and Ratwani (2015) applied an unsupervised topic model to patient safety data to uncover themes within patient safety event reports. Topic modeling has been used to analyze news articles and media reports to reveal topics within various sources of health communication (Liu et al., 2016). Gurcan and Cagiltay (2019) used a probabilistic topic model to identify essential knowledge and skills for big data software engineering, a discipline of data science. Using Latent Dirichlet Allocation (LDA), Gurcan and Cagiltay (2019) analyzed online job advertisements and developed a competency taxonomy for big data software engineering based on the topics that emerged.

Aspects of topic modeling that make it an increasingly useful tool include its applicability and variety of approaches. Another useful function of topic model algorithms is the ability to analyze patterns in different kinds of data, such as genetics data (Liu et al., 2016), aviation incident report data (Kuhn, 2019), healthcare data (Prasad et al., 2021; Yang, 2022), social network (Hong & Davidson, 2010; Lossio-Ventura et al., 2021), and even image data (Zhou et al., 2016). To increase predictive power and interpretability, applications of topic models can be integrated with other statistical learning models (Churchill & Singh, 2022).

In addition to applicability, another strength of topic models is the varied approaches researchers can utilize. This variety enables researchers to choose the most appropriate method based on their data and research objectives. Standard topic model approaches include a basic approach: Latent Dirichlet Allocation (LDA); approaches with advanced topic relationships: correlated topic model (CTM), structural topic model (STM); time-based: dynamic topic models, continuous-time topic modeling; and a short text optimized approach: bi-term topic model (BTM) (Vayansky & Kumar, 2020). For further information, see Vayansky and Kumar's (2020) detailed review of each of these standard topic model approaches. All topic modeling techniques have the advantage of being able to identify relevant themes in vast amounts of unstructured, non-numerical data. For academics and practitioners in applied domains, methods for integrating and organizing such data are especially valuable (Valdez et al., 2021).

# Topic modeling and teams research

Despite the incorporation of various NLP techniques within the methodology of a handful of recent studies (see Berdanier et al., 2020; Katz et al., 2021; Wang et al., 2019), there are few applications of topic modeling within team research. A search for studies using topic modeling on team data provided one example worth mentioning. Zhang and colleagues (2018) utilized topic modeling in their assessment of social interaction's relationship between self-report mood and perceived cohesion in teams. Using topic modeling techniques, the researchers were able to identify common behaviors demonstrated at different times, which allowed for an examination of the dynamics of social interactions throughout the duration of the mission.

Within engineering education, applications of NLP have been limited (Katz et al., 2021). There are a few noteworthy examples of topic modeling used within engineering design team research and engineering education research. Topic modeling was utilized by Gyory et al. (2021) to computationally analyze team discourse and identify the effects of process management on engineering design teams. This study built upon their previous research efforts (Gyory et al., 2018; Gyory et al., 2019) examining the dynamics of collaboration in engineering design teams. To better identify which people can contribute the most improvement to the overall design project, Ball and Lewis (2020) utilized topic modeling to distinguish individual skills and project requirements. Johri et al. (2011) leveraged topic modeling techniques to identify and analyze major topics of interest that have emerged within the field of engineering education. In summary, topic modeling has emerged within team research, but is still largely underutilized.

Team researchers have the potential to make significant advances within their respective fields by utilizing topic modeling and other NLP techniques. Researchers can use this valuable tool to benefit research efforts beyond traditional methodological approaches. Topic modeling provides the power to tap into qualitative data and yield results that will advance research and practice. There is not a need to revolutionize the kind of data being collected (perhaps that counter argument could be made another time), rather there is an advantage to revolutionizing the way data are analyzed to provide better comprehension of team dynamics and higher quality data-based recommendations for practice. Teams often generate a substantial amount of textual data through communication channels such as emails, meeting minutes, and project documentation.

Topic modeling can be applied to these textual data sources to identify recurring themes, topics, or discussions within team communication. The present study serves as an example of how social sciences (e.g., psychology) can benefit from incorporating topic modeling and related approaches.

Topic modeling enables researchers to tap into valuable information provided by qualitative data associated with team activities, processes, and interactions to gain insight into how team members' experiences and perceptions of team processes and emergent states impact their actions and interactions with other team members, as well as their perceptions of team outcomes. Detecting changes in topics over time can help researchers understand how team outcomes evolve, how interventions or changes in team processes impact outcomes, and how emergent states develop or fluctuate over the course of a project or collaboration. Understanding the themes that emerge within team feedback can provide insights into the factors that contributed to the development of positive or negative emergent states and their impact on team outcomes. Extracting latent topics can provide insights into the key issues, challenges, or priorities that influence team outcomes. For example, topic modeling might reveal topics related to project milestones, task assignments, resource allocation, coordination efforts, or potential obstacles to team success. Using this analytical method can advance team research by providing a way to efficiently analyze qualitative data and uncover insights that contribute to a better, more holistic understanding of team dynamics. Thus, the following research question was posed as:

Research Question 1: To what extent can topic modeling techniques reveal themes pertaining to team processes and emergent states, including the ones quantitatively measured by the ITP metrics team dynamic assessment, and uncover themes related to additional team processes and emergent states or contextual factors that were not directly measured by the assessment?

Considering both the existing research and potential to uncover additional insights into team processes using an advanced qualitative approach, I analyzed the open-ended feedback comments from the team dynamics assessment using Structural Topic Modeling (STM). The utilization of topic modeling in the current study was intended to provide additional context to the relationships between perceptions of team processes, emergent states, and outcomes. The broader context in which teams work is particularly relevant to enhancing the understanding of how team constructs emerge within the team context throughout the project timeline (Costa et al., 2017). Collecting qualitative data and utilizing topic model methods advances team research by providing contextual insight that can assist teams in better preparing for future team efforts. The current study contributes to the scarcity of research leveraging NLP methods within team-focused studies by using topic modeling to evaluate team-level feedback as an effort to bridge the gap between NLP research and team research.

To determine the most appropriate topic modeling procedure that is best suited for the research objectives, it is imperative for researchers to understand how the models and their respective underlying algorithms differ from one another (Vayansky & Kumar, 2020). Based on my review of the topic modeling literature, current best practices for

applying topic modeling to qualitative data were followed (e.g., Banks et al., 2018, Churchill & Singh, 2022; Green et al., 2023; Vayansky & Kumar, 2020). Consistent with the procedure for quantitative analyses, the qualitative analyses were conducted using the statistical programming language R and its IDE, RStudio.

I began by pre-processing the data, which involves tokenization (reducing sentences to individual words or "tokens"), cleaning (creating lower case tokens, removing white space, punctuation, and numbers), and removing stop words (e.g., "and", "but", "the"). It is important to note that common text preprocessing choices have consequences on the resulting corpus. Guidance from Denny and Spirling's (2017) evaluation of the varying effects of preprocessing decisions was followed within the current study. Another important text pre-processing consideration is the removal of infrequent words, also known as sparse terms. Following Banks et al.'s (2018) recommendations, the minimum number of documents in which each word must appear was set (e.g., two-document minimum for small sample sizes). For the last pre-processing step, I determined whether to use unigrams or bi-grams for my analysis. Analyzing with bi-grams would use, for example, "Engineering Department " as one token rather than using "Engineering" and "Department" as separate tokens. Once pre-processing was complete, I followed the topic modeling procedure. Details on these steps are outlined in the results chapter.

Since I took an exploratory approach, I began by iteratively exploring the number of topics that best suited my topic model. The need for parsimony and interpretability is a key factor influencing the number of topics (Banks et al., 2018). Topic models are

unsupervised probabilistic models; therefore, after the hidden structure of the documents is revealed by model, the researcher is responsible for interpreting the results in an informative manner (Denny & Spirling, 2017). The number of topics was determined after assessing several diagnostic measures. Explanation of these diagnostic measures is included in the results chapter. Then, I examined the topic network structure which illustrates correlations between topics and contributes valuable information for the evaluation of emerging constructs' dimensionality (Banks et al., 2018). The identified topics were used to provide further insight into how team processes and states affect team outcomes to answer any questions that result from the quantitative analyses or provide support for conclusions drawn from the quantitative results. The qualitative analysis of feedback from team members was intended to reveal additional contributing factors to provide more information about the context or environment which might not be captured by the quantitative measures within the ITP metrics team dynamics assessment, thus addressing *Research Question 1*. The challenge for researchers building theoretical models is accounting for the dynamic interrelationships between the included constructs and emergent concepts (Gioia et al., 2012). Extending beyond an inspection of the static data structure and considering the connections among emergent concepts and unfolding processes enables researchers to provide potential theoretical insights that would otherwise not be apparent (Gioia et al., 2012).

#### CHAPTER FIVE

## RESULTS

## Analytical plan

All statistical analyses for this project were carried out using R 4.3.3 (R Core Team, 2024) and RStudio with the *dplyr* (v1.1.4; Wickham et al., 2023), *Hmisc* (v5.1-1; Harrell, 2023), lavaan (v06.17; Rosseel, 2012), multilevel (v2.7; Bliese, 2022), naniar (v1.1; Cook, 2023), *nlme* (v3.1-164; Pinheiro & R Core Team, 2023), *psych* (v2.4.1; Revelle, 2024), rms (v6.7-1; Harrell, 2023), stats (R Core Team, 2024), stm (Roberts et al., 2019), tidyr (v1.3.1; Wickham & Girlich, 2024) packages. All R code for these analyses is available in Supplementary Materials. Preparing the data for analysis involved reverse coding three of the Psychological Safety items so that all construct items were coded such that higher scores represented higher levels of the construct. There were two response checks in the assessment given at time one, as well as the one given at time two. The 74 cases that missed at least one of the four response checks were removed prior to data analysis. As a result of removing cases that did not pass the response check requirement, there were teams that had fewer than three members. Only teams with three or more members were included in the final data. Initially, there were 518 individuals split into 135 teams. As a result of removing cases that did not pass the response check criteria and cases that were not a part of a team with three or more members, there were a total of 403 individuals that made up 114 teams.

Pearson's correlations between all time one and time two team variables were calculated. Additionally, the descriptive statistics (i.e., mean, standard deviations) for

each measure was calculated. Each scale's reliability was measured using the *alpha* function from the psych R package. The Cronbach's alpha for all time one and time two scales is reported in Table 1. All scale reliabilities were .71 or greater. All multiple linear regression analyses were completed using team level constructs. To justify aggregating the individual data to the team level, within-group agreement indices were estimated. The section on within-group agreement in this chapter delves further into details about these calculations.

## Within-Group Agreement

The within-group agreement estimates were calculated using  $r^*w_{G(J)}$ . As previously stated, this modified  $r_{WG(J)}$  formula is used for multiple item measures. The  $r^*w_{G(J)}$  index is calculated by taking the average item variability as the Observed Group Variance and using the average item variability in the numerator of the  $r_{WG}$  formula ( $r^*w_G$ = 1- (Observed Group Variance/ Expected Random Variance)). Therefore, the  $r^*w_{G(J)}$ does not increase as the number of items in the scale increases. Using the *rwg.j.lindell* function within the multilevel R package (Bliese, 2022), the  $r^*w_{G(J)}$  index was calculated for each scale. The variance from a rectangular distribution was used as the random variance. The *rwg.j.lindell* function uses a value of 2 for rectangular distributions when there are five response options (i.e., strongly disagree to strongly agree) and uses values calculated from the formula ( $A^2 - 1$ )/12 where A is the number of response options for instances when there are not five response options. Psychological safety was the only measure with seven response options and the random variance was adjusted according to this formula.

A widely applied cut-off criterion of .70 has been used to justify aggregation of individual-level data to group-level measures (Biemann et al., 2012; James et al., 1984; Lance et al., 2006). However, this arbitrary cutoff has been heavily criticized and argued as not useful for justifying aggregation in some models (LeBreton & Senter, 2008). According to Woehr et al.'s (2015) review of cutoff values for common aggregation indices, the "rules of thumb" suggest that 0.00-0.30 indicates lack of agreement, 0.31-0.50 indicates weak agreement, 0.51-0.70 moderate agreement, 0.71-0.90 strong agreement, 0.91-1.00 very strong agreement (Lance et al., 2006; LeBreton & Senter, 2008). Woehr and colleagues (2015) used the phrase "rules of thumb" to refer to "practical significance or the value needed to demonstrate sufficient agreement or consistency to justify aggregation rather than statistical significance (i.e., value which is greater than chance agreement or consistency)" (p.728). Additionally, LeBreton and colleagues (2023) suggested that setting criteria to guide or justify aggregation related decisions involves several considerations including how important agreement is within the context of the research hypotheses and the quality of measures. They also argued different constructs warrant varying levels of agreement. For example, weaker agreement exists when variability exists in group members' perceptions of certain measures, such as team satisfaction; therefore, strong agreement might not be necessary. In contrast, strong agreement would be warranted when raters are assessing constructs which are being used to make critical decisions (e.g., hiring). Taking the research context and measure quality into consideration (LeBreton et al., 2023), the cutoff criteria for aggregation was .51 or greater. This allowed teams with moderate to very strong agreement to be included in the

analyses. If a team did not meet the aggregation criteria for a measure (e.g., role clarity), then their data for that measure was considered not applicable (N/A) and coded as such. A list of the team whose data points were removed for time one variables are in Table 10 and the data for time two are in Table 11. A total count of data points removed for each variable at both time points is provided in Table 12. Only removing a team's scores for measures that were below .51 allowed the team's scores for other measures to remain included.

## ICC(1) and ICC(2)

Estimates of ICC(1) and ICC(2) were calculated using the *mult.icc* function from the multilevel R package. This function accounts for groups of varying sizes and uses a grouping variable that identifies the groups from which the variables originated. LeBreton emphasized the critical importance of ICC(1) for "demonstrating the nonindependence of lower-level units due to their nesting within higher-level units" (p. 243). Providing information about the reliability of group means (ICC2) is also important when there is an aggregation of scores. Since individual data were aggregated to the team level, ICC(1) and ICC(2) values were computed.

## **Data imputation**

As previously noted, after within-group agreement indices for all measures were calculated using  $r_{WG(J)}$ , the data points for variables which teams did not meet aggregation criteria were coded as "N/A". For example, one team had a  $r_{WG(J)}$  value of .47 for strategy formulation, which does not meet the aggregation cutoff, thus that team's strategy formulation score (team level) was coded as "N/A". The proportion of missing

values was calculated using the *prop\_miss* function in the naniar R package (Tierney & Cook, 2023). The data had 9.3% of missing values. The number of missing values per variable and per team were also examined. The naniar package provides a function (*mcar\_test*) to conduct a statistical test to assess whether the missing data conform to the Missing Completely at Random (MCAR) assumption. The result of this test suggests that the observed patterns of missingness in the data is unlikely to occur by random chance alone and there may be some systematic pattern to the missing data (*MCAR* = 1095.20, *p* < .0001).

Taking into consideration the low percentage of missing values and the value of the remaining data for each team, data imputation was used to preserve all cases and conduct the series of multiple linear regressions. Using data imputation allows valuable information to be preserved that would otherwise be lost if incomplete cases were deleted (Jadhav et al., 2019). Research has shown that using multiple imputation (MI) serves better than listwise deletion (King et al., 2001). Several studies have compared the performance of different data imputation methods (e.g., Horton & Kleinman, 2007; Jadhav et al., 2019; Penone et al., 2014). The Hmisc R package was used to conduct data imputation for the missing team scores. Details on the use of the functions within this package are outlined in the following section.

## **Regression Analyses**

A series of multiple linear regressions was tested for each model. The *aregImpute* function in the Hmisc package was used to generate a pooled imputed data set. Briefly, the *aregImpute* function accounts for all aspects of uncertainty in the missing data

imputations by using bootstrapping to approximate the process of generating predicted values from a full Bayesian predictive distribution (Harrell, 2023). The function includes arguments for specifying the data, the number of imputations, method type, type of matching, and more. For the arguments included in the *aregImpute* function in the current data analysis, the data specified was the dataset with missing values, the number of imputations was 10, the method type was "regression", and type of matching was predictive mean matching. See R documentation for *aregImpute* {Hmisc} for more details including the sequence of steps the algorithm is following.

## Hypothesis 1

A multiple linear regression was conducted to examine the relationships between perceptions of time two team potency and time one perceptions of strategy formulation, role clarity, team monitoring and backup, goal progression, and coordination. A linear model was fitted to predict perceptions of team potency (T2) with perceptions of strategy formulation, role clarity, team monitoring and backup, goal progression, and coordination (T1). The model explains a statistically significant portion of variance (F(5,108) = 18.14, p < .01, adj.  $R^2 = .43$ ). This suggests that 43% of the variance in perception of team potency is explained by perceptions of strategy formulation, role clarity, team monitoring and backup, goal progression, and coordination. The effect of perceived role clarity (T1) was statistically significant with t(108) = 3.16, p < .01,  $\beta = .39$ . The results suggest that for every one unit increase in perceived role clarity there is a .39-point increase in perceived team potency. Thus, *Hypothesis 1b* was supported. Perceptions of strategy formulation, team monitoring and backup, monitoring goal progression, and coordination

were non-significant predictors of perceived team potency. The results of the linear regression are in Table 2.

## Hypothesis 2

A multiple linear regression was conducted to examine the relationships between perceptions of time two team satisfaction and time one perceptions of cooperative conflict management, trust, and psychological safety. A linear model was fitted to predict perceived team satisfaction (T2) with perceived cooperative conflict management, trust, and psychological safety (T1). The model explains a statistically significant portion of variance  $(F(3,110) = 30.13, p < .01, adj, R^2 = .44)$ . This suggests that 44% of the variance in perception of team potency is explained by perceptions of cooperative conflict management, trust, and psychological safety. The effect of perceived cooperative conflict management (T1) was statistically significant with t(110) = 6.09, p < .01,  $\beta = .55$ . The results suggest that for every one unit increase in perceived cooperative conflict management there is a .55-point increase in perceived team satisfaction. This provides support for Hypothesis 1a. The effect of perceived trust (T1) was statistically significant with t(110) = 2.28, p < .05,  $\beta = .24$ . The results suggest that for every one unit increase in perceived trust there is a .24-point increase in perceived team satisfaction. This provides support for Hypothesis 1b. The effect of perceived psychological safety (T1) was statistically significant with t(110) = -2.45, p < .05,  $\beta = -.17$ . However, this does not support *Hypothesis 1c* which predicted a positive relationship between perceived psychological safety and perceived team satisfaction. I speculate that this unexpected finding is a result of low variance at the team level and does not reflect the actual effects
of perceived psychological safety. Perhaps the fact that psychological safety had 15 missing data values, thus this variable had more imputed values, contributed to this finding. The results for this regression are in Table 3.

#### Hypothesis 3a

This series of multiple linear regression analyses were conducted to examine the relationships between perceptions of time one team satisfaction and team processes (strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, and cooperative conflict management) and team emergent states (trust and psychological safety). A linear model (estimated using OLS) was fitted to predict perceptions of team satisfaction (T1) with strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, cooperative conflict management, trust, and psychological safety (all T1). The model explains 67% of the variance in the outcome and is statistically significant. This suggests that 67% of the variance in perception of team satisfaction is explained by perceptions of strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, cooperative conflict management, trust, and psychological safety. The effect of the perception of team strategy formulation (T1) was statistically significant with t(105) =2.54, p < .05,  $\beta = .24$ . This suggests that for every one unit increase in perception of team strategy formulation there is a .24-point increase in perception of team satisfaction. The effect of the perception of team coordination (T1) was statistically significant with t(105)= 2.82, p < .01,  $\beta = .34$ . This suggests that for every one unit increase in perception of team coordination there is a .34-point increase in perception of team satisfaction. The

effect of perception of team trust was statistically significant with t(105) = 3.34, p < .01,  $\beta = .41$ . This suggests that for every one unit increase in perception of team trust there is a .41-point increase in perception of team satisfaction. Perceptions of role clarity, team monitoring and backup, monitoring goal progression, cooperative conflict management, and psychological safety were non-significant predictors of perceived team satisfaction (T1).

A second model was fitted to predict team satisfaction (T1) with strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, and cooperative conflict management (all T1). Model 2 (reduced model) explains a statistically significant proportion of variance ( $adj.R^2 = .66$ ). This suggests that 66% of the variance in perception of team satisfaction is explained by perceptions of strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, and cooperative conflict management. The effect of perception of team strategy formulation (T1) was statistically significant with t(107) = 2.69, p < .01,  $\beta = .26$ . This suggests that for every one unit increase in perception of team strategy formulation there is a .26-point increase in perception of team satisfaction. The effect of perception of team cooperative conflict management (T1) was statistically significant with t(107) = 2.96, p < 100.01,  $\beta = .27$ . This suggests that for every one unit increase in perception of team cooperative conflict management there is a .27-point increase in perception of team satisfaction. The effect of perception of team coordination (T1) was statistically significant with t(107) = 3.28, p < .01,  $\beta = .39$ . This suggests that for every one unit increase in team coordination there is a .39-point increase in perceptions of team

satisfaction. Perceptions of role clarity, team monitoring and backup, and goal progression were non-significant predictors of perceived team satisfaction (T1).

It appears that Model 1 explains slightly more variability in team satisfaction (T1) than Model 2. A partial F test was conducted to determine whether the change in  $R^2$  was statistically significant. The change in  $R^2 = .08$  and the partial F test was statistically significant, F(2,105) = 13.25, p < .001. Thus, based on the model comparison, Model 1 (full model) is preferred over the simpler Model 2.

A third model was fitted to predict team satisfaction (T1) with trust (T1) and psychological safety (T1). Model 3 explains a statistically significant proportion of variance (*adj.*  $R^2 = .53$ ). This suggests that 53% of the variance in perception of team satisfaction is explained by perceptions of trust and psychological safety. The effect of perception of team trust (T1) was statistically significant with t(111) = 9.56, p < .01,  $\beta =$ .71. This suggests that for every one unit increase in team trust there is a .71-point increase in perception of team satisfaction. Perception of psychological safety (T1) was a non-significant predictor of perceived team satisfaction (T1).

Model 3 explains 53% of the variance in team satisfaction (T1), so it appears that Model 1 explains more variability. A partial F test was conducted to determine whether the change in  $R^2$  was statistically significant. The change in  $R^2 = .14$  and the partial F test was statistically significant, F(6,105) = 7.66, p < .001. Thus, based on the model comparison, Model 1 is preferred over the simpler Model 3.

The results of the series of multiple linear regression analyses revealed that there was a statistically significant relationship between perception of team satisfaction (T1)

and perceptions of strategy formulation (T1), cooperative conflict management (T1), coordination (T1), and trust (T1), respectively. The full model (Model 1) provided the best fit for the data. Perceived team trust (T1), a team emergent state, had the largest effect (.41) on perceived team satisfaction followed by team coordination (.34) and team strategy formulation (.24). Therefore, contrary to Hypothesis 3a, the findings did not support the notion that team members' perceptions of team processes would have a stronger influence than perceptions of team emergent states on team satisfaction at time one. The results of this series of multiple linear regressions are in Table 4.

### Hypothesis 3b

Multiple linear regression analyses were conducted to examine the relationships between perceptions of time one (T1) team potency and team processes (strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, and cooperative conflict management) and team emergent states (trust and psychological safety). A linear model (estimated OLS) was fitted to predict perception of team potency (T1) with perceptions strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, cooperative conflict management, trust, and psychological safety (all T1). Model 1 explains 58% of the variance in the outcome and is statistically significant. This suggests that 58% of the variance in perception of team potency is explained by perceptions of strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, cooperative conflict management, trust, and psychological safety. The effect of the perception of team role clarity (T1) was statistically significant with t(105) = 3.37, p < .01,  $\beta = .32$ . This suggests that for every

one unit increase in perception of team role clarity there is a .32-point increase in perception of team potency. The effect of the perception of team trust (T1) was statistically significant with t(105) = 3.06, p < .01,  $\beta = .27$ . This suggests that for every one unit increase in perception of team trust there is a .27-point increase in perception of team potency. The effect of the perception of team psychological safety (T1) was statistically significant with t(105) = -2.61, p < .01,  $\beta = -.20$ . This suggests that for every one unit increase in perception of team psychological safety there is a .20-point decrease in perception of team potency. I speculate that this unexpected finding is a result of low variance in psychological safety at the team level or the fact that psychological safety had 15 missing data values at time one, thus this variable had more imputed values. The perceptions of strategy formulation, goal progression, coordination, and cooperative conflict management were non-significant predictors of perceived team potency (T1).

A second model was fitted to predict team potency (T1) with strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, and cooperative conflict management (all T1). Model 2 explains a statistically significant proportion of variance (*adj.*  $R^2 = .52$ ). This suggests that 52% of the variance in perception of team potency is explained by perceptions of strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, and cooperative conflict management. The effect of perception of team role clarity (T1) was statistically significant with *t*(107) = 3.77, *p* < .01,  $\beta$  = .39. This suggests that for every one unit increase in perception of team role clarity there is a .39-point increase in perception of team potency. The effect of perception of team coordination (T1) was statistically

significant with t(107) = 2.04, p < .05,  $\beta = .27$ . This suggests that for every one unit increase in perception of team coordination there is a .27-point increase in perception of team potency. The perceptions of strategy formulation, team monitoring and backup, goal progression, and cooperative conflict management were non-significant predictors of perceived team potency (T1).

It appears that Model 1 explains more variability in team potency (T1) than Model 2. A partial F test was conducted to determine whether the change in  $R^2$  was statistically significant. The change in  $R^2 = .06$  and the partial F test was statistically significant, F(2,105) = 8.74, p < .001. This indicates that the full model provided a significantly better fit to the data than the reduced model. Thus, based on the model comparison, Model 1 is preferred over Model 2.

A third model was fitted to predict team potency (T1) with trust (T1) and psychological safety (T1). Model 3 explains a statistically significant proportion of variance (*adj.*  $R^2 = .41$ ). This suggests that 41% of the variance in perception of team potency is explained by perceptions of trust and psychological safety. The effect of perception of team trust (T1) was statistically significant with *t*(111) = 10.79, *p* < .01,  $\beta$  = .67. This suggests that for every one unit increase in team trust there is a .67-point increase in perception of team potency. The perception of psychological safety was a non-significant predictor of perceived team potency (T1).

It appears that Model 1 explains more variability in team potency (T1) than Model 3. A partial F test was conducted to determine whether the change in  $R^2$  was statistically significant. The change in  $R^2 = .19$  and the partial F test was statistically significant, F(6,105) = 8.65, p < .001. This indicates that the full model provided a significantly better fit to the data than the reduced model. Thus, based on the model comparison, Model 1 is preferred over Model 3.

The results of the series of multiple linear regression analyses revealed that there was a statistically significant relationship of perceived team potency (T1) with perceptions of role clarity (T1), coordination (T1), trust (T1), and psychological safety (T1), respectively. Model 1 provided the best fit for the data. Perceived team role clarity (T1), a team process, had the largest effect on team potency (T1). This provides partial support for Hypothesis 3b and the notion that team members' perceptions of team processes would have a stronger influence than perceptions of team emergent states on team potency at time one. The results of this series of multiple linear regressions are in Table 5.

## Hypothesis 4a

A series of multiple linear regression analyses were conducted to examine the relationships between perceptions of time two (T2) team satisfaction and team processes (strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, and cooperative conflict management) and team emergent states (trust and psychological safety). A linear model (estimated using OLS) was fitted to predict perceived team satisfaction (T2) with perceptions of strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, cooperative conflict management, trust, and psychological safety (all T2). Model 1 explains 77% of the variance in perceived team satisfaction (T2) and is statistically significant. This suggests

that 77% of the variance in perception of team satisfaction (T2) is explained by perceptions of strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, cooperative conflict management, trust, and psychological safety (all T2). The effect of perceived team coordination (T2) was statistically significant with t(105) = 2.28, p < .05,  $\beta = .34$ . This suggests that for every one unit increase in perception of team coordination there is a .34-point increase in perception of team satisfaction. The effect of the perception of team trust (T2) was statistically significant with t(105) = 4.60, p < .01,  $\beta = .48$ . This suggests that for every one unit increase in perception of team trust there is a .48-point increase in perception of team satisfaction. The effect of perceived team psychological safety (T2) was statistically significant with t(105) = 2.56, p < .01,  $\beta = .15$ . This suggests that for every one unit increase in perception of team psychological safety there is a .15-point increase in perception of team satisfaction. The perceptions of strategy formulation, role clarity, team monitoring and backup, goal progression, and cooperative conflict management (all T2) were non-significant predictors of perceived team satisfaction (T2).

A reduced model was fitted to predict team satisfaction (T2) with strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, and cooperative conflict management (all T2). Model 2 explains a statistically significant proportion of variance (*adj.*  $R^2 = .70$ ). This suggests that 70% of the variance in perception of team satisfaction is explained by perceptions of strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, and cooperative conflict management. The effect of the perception of team cooperative conflict management (T2) was statistically significant with t(107) = 2.28, p < .05,  $\beta = .25$ . This suggests that for every one unit increase in perception of team cooperative conflict management there is a .25-point increase in perception of team satisfaction. The effect perceived team coordination (T2) was statistically significant with t(107) = 3.84, p < .01,  $\beta = .54$ . This suggests that for every one unit increase in perception of team coordination there is a .54-point increase in perception of team satisfaction. The perceptions of strategy formulation, role clarity, team monitoring and backup, and goal progression (all T2) were non-significant predictors of perceived team satisfaction (T2).

It appears that Model 1 explains more variability in team satisfaction (T2) than Model 2. A partial F test was conducted to determine whether the change in  $R^2$  was statistically significant. The change in  $R^2 = .07$  and the partial F test was statistically significant, F(2,105) = 17.53, p < .001. This indicates that the full model provided a significantly better fit to the data than the reduced model. Thus, based on the model comparison, Model 1 is preferred over Model 2.

A third model was fitted to predict team satisfaction (T2) with trust (T2) and psychological safety (T2). Model 3 explains a statistically significant proportion of variance (*adj.*  $R^2 = .73$ ). This suggests that 73% of the variance in perception of team satisfaction is explained by perceptions of trust and psychological safety. The effect of perception of team trust (T2) was statistically significant with t(111) = 11.52, p < .01,  $\beta =$ .74. This suggests that for every one unit increase in team trust there is a .74-point increase in perception of team satisfaction. The effect of perceived team psychological safety (T2) was statistically significant with t(111) = 3.21, p < .01,  $\beta = .20$ . This suggests that for every one unit increase in team psychological safety there is a .20-point increase in perception of team satisfaction.

It appears that Model 1 explains more variability in team satisfaction (T2) than Model 2. A partial F test was conducted to determine whether the change in  $R^2$  was statistically significant. The change in  $R^2 = .06$  and the partial F test was statistically significant, F(6,105) = 4.65, p < .001. This indicates that the full model provided a significantly better fit to the data than this reduced model. Thus, based on the model comparison, Model 1 is preferred over Model 3.

The results of the series of multiple linear regression analyses revealed that there was a statistically significant relationship of perceived team satisfaction (T2) with perceptions of coordination (T2), trust (T2), and psychological safety (T2). Model provided the best fit to the data. Perceived team trust (T2), a team emergent state, had the largest effect (.48) on perceived team satisfaction followed by team coordination (.34) and psychological safety (.15). Thus, these findings provide partial support for Hypothesis 4a and the notion that team members' perceptions of team emergent states would have a stronger influence than perceptions of team processes on team satisfaction at time two. The results of this series of linear regressions are in Table 6.

# Hypothesis 4b

Another series of multiple linear regression analyses were conducted to examine the relationships hypothesized between perceptions of team potency (T2) and strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, and cooperative conflict management, trust, and psychological safety (all T2). A linear

model (estimated using OLS) was fitted to predict team potency (T2) with strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, and cooperative conflict management, trust, and psychological safety (all T2). The model explains a statistically significant proportion of variance ( $adj.R^2 = .75$ ). This suggests that 75% of the variance in perceived team potency is explained by perceptions of strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, cooperative conflict management, trust, and psychological safety. The effect of perceived team coordination (T2) was statistically significant with t(105) = 2.37, p < .05,  $\beta = .30$ . This suggests that for every one unit increase in perception of team coordination there is a .30-point increase in perception of team potency. The effect of perceived team trust (T2) was statistically significant with t(105) = 4.33, p < .01,  $\beta = .46$ . This suggests that for every one unit increase in perception of team coordination there is a .46-point increase in perception of team potency. The effect of perceived psychological safety (T2) was statistically significant with t(105) = -2.30, p < .05,  $\beta = -.13$ . This suggests that for every one unit increase in perception of team coordination there is a .13-point decrease in perception of team potency. As previously noted, I speculate that this unexpected finding is a result of low variance in psychological safety at the team level or the fact that psychological safety had 21 missing data values at time two, thus this variable had more imputed values compared to other model variables. The perceptions of strategy formulation, role clarity, team monitoring and backup, goal progression, and cooperative conflict management (all T2) were non-significant predictors of perceived team potency (T2).

A second model was fitted to predict team potency (T2) with strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, and cooperative conflict management (all T2). Model 2 explains a statistically significant proportion of variance (*adj.*  $R^2 = .70$ ). This suggests that 70% of the variance in perceived team potency is explained by perceptions of strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, and cooperative conflict management. The effect of perceived team coordination (T2) was statistically significant with *t*(107) = 4.04, *p* < .01,  $\beta$  = .45. This suggests that for every one unit increase in perception of team coordination there is a .45-point increase in perception of team potency. The perceptions of strategy formulation, role clarity, team monitoring and backup, goal progression, and cooperative conflict management (all T2) were nonsignificant predictors of perceived team potency (T2).

It appears that Model 1 explains more variability in team potency (T2) than Model 2. A partial F test was conducted to determine whether the change in  $R^2$  was statistically significant. The change in  $R^2 = .05$  and the partial F test was statistically significant, F(2,105) = 11.56, p < .001. This indicates that the full model provided a significantly better fit to the data than the reduced model. Thus, based on the model comparison, Model 1 is preferred over Model 2.

A third model was fitted to predict team potency (T2) with trust (T2) and psychological safety (T2). Model 3 explains a statistically significant proportion of variance (*adj*.  $R^2 = .67$ ). This suggests that 67% of the variance in perceived team potency is explained by perceptions of trust and psychological safety. The effect of perceived team trust (T2) was statistically significant with t(111) = 13.47, p < .01,  $\beta = .86$ . This suggests that for every one unit increase in team trust there is a .86-point increase in perception of team potency. The perception of psychological safety (T2) was a non-significant predictor of the perceived team potency (T2).

It appears that Model 1 explains more variability in team potency (T2) than Model 3. A partial F test was conducted to determine whether the change in  $R^2$  was statistically significant. The change in  $R^2 = .09$  and the partial F test was statistically significant, F(6,105) = 7.06, p < .001. This indicates that the full model provided a significantly better fit to the data than this reduced model. Thus, based on the model comparison, Model 1 is preferred over Model 3.

The results of the series of multiple linear regression analyses revealed that there was a statistically significant relationship of perception of team potency (T2) with perceptions of coordination (T2), trust (T2), and psychological safety (T2). Model 1 provided the best fit for the data. Perceived team trust (T2) had the largest effect (.46) on perceived team potency followed by coordination (.30) and psychological safety (-.13). Trust (T2), a team emergent state, had a greater effect on perception of team potency (T2) than coordination (T2), but psychological safety (T2) had a smaller effect compared to the team process of coordination (T2). Thus, the findings partially supported Hypothesis 4b and the notion that team members' perceptions of team emergent states would have a stronger influence than perceptions of team processes on team potency at time two. The results of this series of linear regressions are in Table 7.

## Hypothesis 5a

Multiple linear regressions were used to examine the relationships with both time one and time two perceptions of trust and psychological safety and time two perceived team satisfaction. Model 1 explains 66% of variance in perceived team satisfaction (T2) and is statistically significant. This suggests that 66% of the variance in perceived team satisfaction is explained by perceived team trust and psychological safety. The effect of perception of team trust (T2) was statistically significant with t(109) = 6.12, p < .01,  $\beta =$ .68. This suggests that for every one unit increase in perception of team trust there is a .68-point increase in perceived team satisfaction (T2). The effect of perceived team psychological safety (T2) was statistically significant with t(109) = 2.34, p < .05,  $\beta = .68$ . This suggests that for every one unit increase in perception of team psychological safety there is a .68-point increase in perception of team satisfaction. The perceptions of trust (T1) and psychological safety (T1) were non-significant predictors of perceived team satisfaction (T2).

The results of this linear regression indicated that there was a statistically significant relationship of perceived team satisfaction (T2) with perceived trust (T2) and psychological safety (T2), respectively. These findings provide support for Hypothesis 5a and for the notion that compared to the perception of the team emergent states at time one, the perception of both trust and psychological safety at time two would have a stronger influence on team satisfaction at time two.

## Hypothesis 5b

Another multiple linear regression was conducted to examine the relationships between the same predictor variables from Hypothesis 5a with team potency (T2). A model was fitted to predict perceived team potency (T2) with perceptions of team trust (T1 and T2) and psychological safety (T1 and T2). The model explains a statistically significant proportion of variance (*adj.*  $R^2 = .63$ ). This suggests that 63% of the variance in team potency (T2) is explained by trust and psychological safety. The effect of perceived team trust (T2) was statistically significant with t(109) = 8.93, p < .01,  $\beta = .84$ . This suggests that for every one unit increase in perception of team trust there is an .84point increase in perceived team potency. The perceptions of trust (T1) and psychological safety (T1 and T2) were nonsignificant predictors of team potency (T2).

The results of this linear regression indicated that there was a statistically significant relationship between perceived team potency (T2) and perceived trust (T2). There was not a significant relationship between the perception of team potency (T2) and either of the team emergent states (T1). This finding provides partial support for the notion that compared to the perception of the team emergent states at time one, the perception of team emergent states at time two would have a stronger influence on team potency at time two. The results for Hypothesis 5a&b are in Table 8.

# **Topic models**

Topic modeling techniques were applied to open-ended text comments regarding team project experience. Respondents were asked to provide feedback at the team level. The prompt was as follows: "Please provide feedback to your team. Remember that your feedback will be anonymous, i.e., they will not know who provided it. Only the assessment administrator can determine who provided each comment. Feedback may be on positive aspects of your team or areas for improvement or both. Your comments should be:

- Specific rather than "we did a job", explain "we did an excellent job in responding to emails in a timely manner".
- Constructive (even when providing negative feedback) rather than "some of us were lazy and didn't pull their weight in the group", explain "at times some of us didn't contribute as much as the rest of the team, and the entire team would benefit if everybody rose up to the challenges."
- Respectful never use abusive language and always address your team members as you would in a professional work setting."

The qualitative feedback from time one and time two were separately analyzed to examine differences between the themes that emerged at each respective time. The advantages to topic modeling include the ability to analyze lists of words through the automatic identification of latent or "hidden" themes, the scalability to thousands of documents without manual (human) coding, and the ability to rate topic likeness and identify the most representative comments (Banks et al., 2018). Although open-ended responses are often collected during research efforts, the analysis of these responses is relatively rare and typically conducted through human coding (Roberts et al., 2014). The present study utilized the qualitative comments from the team assessments and applied topic modeling as an alternative to manual coding. This analysis was exploratory in

nature and I would recommend using this approach along with human coding if a researcher intends to use results for hypothesis testing.

Specifically, the structural topic model (STM) was used. Roberts and colleagues (2013) developed the STM building off of existing approaches (LDA; Blei et al., 2003) to allow users to incorporate the specific structure of their corpus. This key innovation allows users to integrate information about each document into the topic model (Roberts et al., 2019). Thus, STM goes beyond traditional topic models, which can identify the number of topics and identify key terms within each topic, by incorporating metadata (information about a document) into the topic estimation (Tonidandel et al., 2022). Using this type of model through the stm R package (Roberts et al., 2019) allowed for a quick analyzation of 403 students' comments about their team project experience. It is worth noting that while the package automates analysis, the overall process involves human decision making to investigate topics.

The stm package was used to prepare the open-ended responses for analyses using the *textProcessor* and *prepDocuments* function, search for a suitable number of topics, fit candidate models, and to generate several visuals to present findings. The same procedure was used to analyze both time one and time two data. The guidelines provided by Weston et al.'s (2023) tutorial were extremely helpful in utilizing the stm package. The preprocessing transformed the text strings (sentences) by removing stop words, numbers, and punctuation, lowering cases, and removing stop words (e.g., "and", "but", "the"). The document prepping ensures document, terms, and metadata are properly synced and removes infrequent words (Roberts et al., 2019). After the data were prepared for

analysis, the *searchK* function was used to identify the ideal number of topics. An advantage of using the stm package is that the researcher does not have to include a specific number of topics; rather the user can assess several diagnostic measures generated by the *searchK* function to determine the number of topics (K) that will best suit the model. I used the *searchK* function to assess candidate models with a range of 2-20 topics. Based on Robert et al.'s recommendation, I used the default initialization method, "Spectral", which is noted to perform extremely well. I plotted the results of the *searchK* and generated a table to take a closer look at the exact diagnostic values. The plots provide visuals of the held-out likelihood, residuals, semantic coherence, and lower bound values across the number of topics (K). Weston and colleagues (2023) recommend examining all four metrics to identify candidate models and note that "ideal solutions yield fewer residuals and higher exclusivity, variational lower bound, and semantic coherence" (p. 4). Previous research has also suggested that semantic coherence and exclusivity provide good tradeoff measures to help choose a K value (Roberts et al., 2014). Semantic coherence refers to internal consistency within a topic and is maximized when the most probable terms in a topic co-occur frequently (Roberts et al., 2014). Exclusivity of a topic is considered high when words are unique to that particular topic (have a high probability under that topic). Taking these recommendations into consideration, I examined all four metrics (using the plots and table) and plotted the semantic coherence and exclusivity.

Upon examining the diagnostic measures, I determined that solutions with 5, 8, and 13 topics would serve as candidate models. As Weston and colleagues (2023) noted

in their topic modeling tutorial, researchers can use their discretion when choosing which models to further evaluate depending on the research goals. I thought it was valuable to use and compare multiple models given that this analysis was intended to explore qualitative data in a non-traditional way and not concerned with finding one model that best fits the data. I was able to compare the topics and related comments across the three candidate models. Comparing models with 5-, 8-, and 13-topic solutions involved examining topic prevalence, solution congruence, frequent and exclusive words, key examples, and correlations among topics. Topic prevalence refers to the likelihood of documents being generated from each topic. The degree to which individual topics are representative of the responses was calculated using the gamma matrices from each model. Solution congruence indicates the degree of semantic overlap (Weston et al., 2023) or similarity across solutions. The solution congruence was estimated using correlations between the topics based on beta matrices from each solution (candidate model).

For each candidate model, I examined the frequent words by plotting the top terms for each topic which are the most likely words to appear for each topic. To examine the exclusive words, I used the *labelTopics* function which provided a list of exclusive words for each topic. I instructed the function to generate the list in order of frequency, but the default output prints different word profiles including highest probability, FREX, Lift, and Score. Refer to Roberts et al.'s (2019) stm R package manual for more details on these profiles. Using the *findThoughts* function, I extracted the top responses associated with specific topics in each candidate model (e.g., the top responses for the

first and fourth topic in the 8-topic solution). This output displays the exact feedback comment and provides a better understanding of what content contributed to a particular topic/theme.

I concluded my examination of candidate models with a couple of additional visualizations. First, I calculated the correlations between topics within a model using the *topicCorr* function in stm. I plotted the correlations in a network graph to visually determine if there were clusters of topics. I calculated topic correlations and generated plots for each candidate model. Lastly, I utilized the *toLDAvis* function to generate an interactive visualization for each model. This function allowed the models created in stm to be visualized using the LDAvis package which creates an interactive web-based visualization of a topic model.

# Time 1

This section summarizes the results of the STM for time two data. I examined models with 5-, 8-, and 13-topic solutions. Frequent words were extracted from each topic and up to 10 were plotted. The list of words plotted were restricted to only include words with a probability of at least .01. The frequent words for the topics in the model with 8 topic solutions are as follows with the words listed in descending probability. For topic 1: able, manner, timely, quality, ideas, tasks, effectively. For topic 2: one, help, needed, class, another, outside, tasks, effort, lab. For topic 3: like, feel, can. For topic 4: together, well, get, overall, works, know, can, complete, communicate, communication. For topic 5: good, done, job, think, time, better, getting, things, assignments, communicating. For topic 6: think, need, design, final, time, conceptual, report,

presentation, will, phase. For topic 7: group, members, deadlines, meeting, always, member, others. For topic 8: great, working, project, job, everyone, far, worked, believe, also.

The top 10 exclusive words for each candidate model were extracted. The exclusive words for the topics in the model with 8 topic solutions are as follows in order of descending frequency. For topic 1: manner, timely, quality, high, ideas, communicated, able, effectively, new, product. For topic 2: another, person, effort, among, example, given, helped, responding, understanding, roles. For topic 3: see, late, ever, less, respectful, responsibilities, like, feel, benefit, wait. For topic 4: works, efficiently, together, appreciate, complete, well, overall, know, communicate, get. For topic 5: getting, good, done, everyones, assignments, sooner, things, date, better, job. For topic 6: final, conceptual, phase, guys, enjoy, items, need, design, turned, presentation. For topic 7: deadlines, weight, difficult, issue, positive, within, meeting, setting, rest, allow. For topic 8: great, yall, say, coming, working, worked, project, presenting, assignment, designs.

I extracted key responses from topics within each candidate model. Excerpts from examples of top responses for Topic 1 in the model with 8 solutions include, "When we needed information regarding the other person's specialty we were able to provide them with it in a timely manner", "We did well with organization of project work and team meetings as well as general time management", "All project work is designated and completed in an efficient and timely manner, and this work is back-checked for completeness and accuracy before submission". The top responses associated with Topic

1 seem to reflect that team members perceived the team as being efficient, having clearly defined roles, coordinated, and communicative. This topic appears to have emerged from comments pertaining to time management and organization leading to positive perceptions of team productivity. Excerpts from the top responses for Topic 4 in the model with 8 solutions include, "Team works well together, sometimes we get off topic and lose productivity, but that's more because we work really well together, not because we are in conflict", "I am very happy with our progress and the way we work together", "I look forward to continuing to work together in the future. I know this is a reliable group". The key responses associated with Topic 4 indicate that the team works well together, does not struggle with conflict, and is satisfied with their team experience. The insights provided by various examinations of topic content into this topic suggest that this theme derived from team feedback related to effective communication and collaboration and team satisfaction.

To explore the correlations between topics within a model, I calculated the topic correlations and generated a network plot to identify possible clusters of topics. The plot for the 8-topic solution did not indicate any particular clusters of topics. This suggests that the topics were not strongly correlated with each other.

Lastly, I used the interactive visualization tool provided by LDAvis. A still shot of this tool is provided in Figure 1. The interactive topic model visualization generated for the 8-topic solution assisted with understanding more about each of the topics. The visual on the right side of the web-based tool illustrates the top 30 most salient terms for a selected topic along with the overall term frequency and estimated term frequency

within a topic. The left side of the tool provides an inter-topic distance map which is a visualization of the topics in a two-dimensional space. The area of each circle is proportional to the amount or percentage of tokens that belong to each topic across the dictionary of words provided. The sliding bar on the top of the right-hand side allows users to adjust the lamba ( $\lambda$ ) value. Small values of  $\lambda$  (near 0) highlight potentially rare, but exclusive terms for the selected topic, and large values of  $\lambda$  (near 1) highlight frequent, but not necessarily exclusive, terms for the selected topic (Sievert & Shirley, 2014).

As previously mentioned, it is often challenging to generate topic labels that are both representative and informative. In previous projects, I have collaborated with fellow researchers to examine the results and we compared the results to existing taxonomies (e.g., leadership frameworks) and used a rater system to come to topic label consensus. This is one way to approach labeling topics. In the current study, I decided to use ChatGPT to assist with the creation of topic labels for this candidate model. I provided ChatGPT with all of the information I was able to extract from the model (as summarized above) and asked for topic labels based on this information. When prompted with this information, the ChatGPT generated text provided topic labels and descriptions. The full text response (including the initial prompt) is listed in the Appendices (see Appendix A). The topic labels that ChatGPT's generated provided are as follows: Topic 1 - Efficiency and Quality Assurance; Topic 2 - Collaborative Effort and Support; Topic 3 - Respectful Communication and Responsibilities; Topic 4 - Team Dynamics and Productivity; Topic 5 - Task Management and Progress Tracking; Topic 6 - Project Planning and Execution;

Topic 7 - Deadline Management and Issue Resolution; Topic 8 - Positive Feedback and Team Motivation. ChatGPT can make mistakes and it is necessary to incorporate human judgment when utilizing this OpenAI platform. For the purposes of this study, the ChatGPT generated text provided labels that can easily be understood. Recall from my discussion of the key responses for Topic 1, I noted that the top responses seemed to reflect that team members perceived the team as being efficient, having clearly defined roles, coordinated, and communicative. In comparison, the ChatGPT generated topic label was Efficiency and Quality Assurance. Similarly, I suggested that the key responses associated with Topic 4 indicate that the team works well together, does not struggle with conflict, and is satisfied with their team experience. The ChatGPT generated topic label was Team Dynamics and Productivity. This is a more generalized label, but nonetheless it covers the idea that the feedback discusses team interactions and dynamics. The creation of a more standardized topic labeling procedure would strengthen the use of topic modeling in the future.

## Time 2

This section summarizes the results of the STM for time two data. I examined models with 5-, 8-, and 13-topic solutions for the sake of consistency with the procedure used for time one data. Frequent words were extracted and up to 10 were plotted. The list of words plotted was restricted to only include words with a probability of at least .01. The frequent words for the topics in the model with 8 topic solutions are as follows with the words listed in descending probability. For topic 1: got, made, complete, times, part, along, ideas, way. For topic 2: working, enjoyed, everyone, guys, help, always, pressure.

For topic 3: semester, really, feel, like, thought, one, yall, best. For topic 4: time, completing, others, communicated, excellent, members, completed, class, quality, tasks. For topic 5: project, believe, overall, finished, member, throughout. For topic 6: well, together, worked, great, job, done, communicating, manner, timely, getting. For topic 7: think, good, job, final, design, overall, report, better, presentation, lot. For topic 8: group, able, get, everyone, done, sure, make, always, needed.

The top 10 exclusive words for each candidate model were extracted. The exclusive words for the topics in the model with 8 topic solutions are as follows in order of descending frequency. For topic 1: along, ideas, met, performed, got, turn, made, focused, times, complete. For topic 2: working, guys, pleasure, weight, pulled, efficient, evenly, dynamic, coming, solid. For topic 3: thought, yall, really, feel, ability, decent, keep, lets, thanks, semester. For topic 4: completing, others, completed, meeting, effectively, management, meet, time, hard, quality. For topic 5: individual, success, portions, teammates, weaknesses, contributed, discuss, needs, believe, strengths. For topic 6: manner, well, together, timely, despite, great, worked, responsibilities, communicating, amazing. For topic 7: final, design, report, good, points, lot, think, conceptual, last, minute. For topic 8: finish, need, staying, issue, beginning, stay, submitting, get, glad, make.

I extracted key responses from topics within each candidate model. Excerpts from examples of top responses for Topic 1 in the model with 8 solutions include, "All of our discussions were productive especially talking about different viewpoints and ideas", "The team did respond well to all team communications…", "As a team we were able to

efficiently complete all presentation slides". These key responses suggest that the team experienced strong communication and a sense of psychological safety that allowed different opinions to be shared. This topic appears to pertain to efficiency resulting from good communication and openness to varying perspectives. Excerpts from examples of top responses for Topic 4 within this model include, "At times our team lacked communication as to what work needed to be done by others and lacked a clear breakup of the work..." and "Communication improved over time, but it could still be refined". The top responses from Topic 4 indicate that the team experienced poor communication and lack of role clarity. This topic seems to have emerged from feedback about hindrances or difficulties. Being able to examine the key responses associated with each topic is a valuable way to examine what aspects of teamwork were being discussed within each theme.

To explore the correlations between topics within a model, I calculated the topic correlations and generated a network plot to identify possible clusters of topics. The plot for the 8-topic solution did not indicate any particular clusters of topics. This suggests that the topics were not strongly correlated with each other. Additionally, I used the LDAvis interactive tool to examine the 8-topic solution the same way as I did for the time one 8-topic solution.

To be consistent with the approach I used for the time one 8-topic solution, I provided ChatGPT with all of the information I was able to extract from the model (as summarized above) and asked for topic labels based on this information. When prompted with this information, the ChatGPT generated text provided topic labels and descriptions.

The full text response (including the initial prompt) is listed in the Appendices (see Appendix B). The topic labels that ChatGPT's generated provided are as follows: Topic 1 - Effective Communication and Collaboration; Topic 2 - Team Dynamics and Supportive Environment; Topic 3 - Reflection on Team Experience and Progress; Topic 4 -Communication and Task Management; Topic 5 - Individual Contribution and Team Success; Topic 6 - Efficient Workflow and Responsibilities; Topic 7 - Quality of Project Deliverables and Presentation; Topic 8 - Issue Resolution and Project Completion. Recall from my discussion of the key responses for Topic 1, I suggested that this topic appears to pertain to efficiency resulting from good communication and openness to varying perspectives. In comparison, the ChatGPT generated topic label was Effective Communication and Collaboration. Upon examining the top responses associated with Topic 4, I noted that this topic emerged from feedback discussing poor communication and lack of role clarity within teams. For Topic 4, the ChatGPT generated topic label was Communication and Task Management.

I chose to analyze the team feedback from time one and time two separately to see if it was possible to determine a difference in the themes that emerged. Given that the first time point in which feedback was collected was early on in the project when team processes were playing a critical role in the team dynamics, I expected that feedback could pertain to perceptions of various team processes (e.g. strategy formulation, role clarity). In contrast, the second time point in which feedback was collected was at the end of the project when teams were able to reflect on the entire experience. Thus, I expected that feedback could include commentary on team constructs that emerged at a team level

as a result of interactions between team members (e.g., trust, psychological safety). By examining the ChatGPT generated topic labels, it appears the topics labels for the time one 8-topic solution were somewhat indicative of team processes. Namely, Topic 5 (Task Management and Progress Tracking), which is similar to monitoring goal progression, Topic 6 (Project Planning and Execution), which could be compared to strategy formulation, and Topic 7 (Deadline Management and Issue Resolution), in which the latter half of the label is similar to (cooperative) conflict management. After examining the ChatGPT generated topic labels for the time two 8-topic solution, it appears that the labels are not distinctly representative of team emergent states. However, the time two labels for this candidate model do suggest that time influenced the emergence of topics. Topic 3 (Reflection on Team Experience and Progress) suggests that feedback comments included reflections about individual's experiences and feelings toward their respective teams. Topic 8 (Issue Resolution and Project Completion) suggests that feedback was related to resolving conflict to overcome challenges and ensure project completion. Despite not having perfectly distinct topics related to both team processes and emergent states, I believe that analyzing the qualitative feedback at each time point provides insight into the team mechanisms that were relevant at that stage of the project.

#### CHAPTER SIX

#### DISCUSSION

Teams serve as the fundamental units of productivity within organizations, and their effectiveness hinges on collaborative efforts and the collective emergence of shared states. Understanding team dynamics is essential for optimizing team performance and achieving desired outcomes in various organizational settings. As researchers advance team research, it is important to consider how these lessons learned can be incorporated into team projects within education programs. Acquiring teamwork skills during an undergraduate program is advantageous for individuals because they can develop these skills prior to beginning their professional careers. In this study, I explored the intricate relationships between the perception of several team processes, emergent states, and their consequential impact on perception of team satisfaction and potency. By examining these dynamics, I aimed to shed light on the mechanisms underlying successful teamwork, providing insights that can inform strategies for enhancing team satisfaction, productivity, and overall effectiveness.

As the reliance on teams continues to grow, it is imperative to understand what aspects of teamwork significantly influence team outcomes. The present study contributes to team literature by providing insight into how perceptions of team processes and emergent states affect team satisfaction and potency. There are certainly additional relationships to explore, but it is important to take an intentional approach when trying to pinpoint underlying mechanisms of team dynamics. One of the goals of the present study is to provide actionable insights to the engineering program leaders and instructors that

will help to improve team projects that are a core component of the curriculum. By collecting student feedback throughout a course project and subsequently analyzing the information, the knowledge gained can be applied to continuously improve team experience and acquisition of teamwork skills. This study demonstrates the impact of team members' perceptions of strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, and cooperative conflict management, trust, and psychological safety. Additionally, valuable contextual information was analyzed using topic modeling to provide a more nuanced comprehension of factors influencing team satisfaction and potency that were not explicitly measured.

## **Discussion of findings**

Based on the original hypothesized models, I expected that 1) perceptions of (a) strategy formulation, (b) role clarity, (c) team monitoring and backup, (d) monitoring goal progression, and (e) coordination would be positively related to perception of team potency; 2) perceptions of (a) cooperative conflict management, (b) trust, and (c) psychological safety would be positively related to perception of team satisfaction; 3) perceptions of team processes at time one would have a greater effect on perceptions of team emergent states at time one; 4) perceptions of team emergent states at time two would have a greater effect on perceptions of team emergent states at time two states at time two states at time two solutions of team processes at time two; 5) perceptions of team emergent states of team emergent states at time two would have a greater effect on team emergent states at time two would have a greater effect on team emergent states at time two would have a greater effect on team emergent states at time two would have a greater effect on team emergent states at time two would have a greater effect on team emergent states at time two would have a greater effect on team emergent states at time two would have a greater effect on team emergent states at time two would have a greater effect on team emergent states at time two would have a greater effect on team emergent states at time two would have a greater effect on team emergent states at time two would have a greater effect on team members' perceptions of team

satisfaction and team potency at time two compared to the time one perceptions of team emergent states.

The results indicated there was a significant positive relationship between perceived team potency (T2) and role clarity(T1). Additionally, the findings suggest that there is a significantly positive relationship between perceived team satisfaction (T2) and perceived cooperative conflict management (T1), as well as perceived trust (T1). The partial support for both Hypothesis 1 and 2 indicates that certain team processes and team emergent states impact perceived team potency and satisfaction. It is important to understand which mechanisms are affecting team outcomes. This knowledge allows people working in teams to focus on key team processes to ensure team goals are achieved. Knowing that team emergent states, such as trust, can positively influence team outcomes provides motivation for developing strong relationships and fostering a shared sense of trust.

The results of the multiple linear regressions revealed that there was a significant positive relationship between perceived team satisfaction (T1) and strategy formulation (T1), coordination (T1), and trust (T1), respectively. There was a significant positive relationship between perceived team potency (T1) and perceptions of role clarity (T1) as well as trust (T1). These findings suggest that perception of certain team processes and team emergent states influence perception of team satisfaction and potency. The partial support for Hypothesis 3a and 3b indicates that perceptions team processes at time one (midpoint of the project) affect perceived team satisfaction and potency. Additionally, trust, which is a team emergent state, impacted these team outcomes. Therefore, it is

necessary to be mindful of both team processes and team emergent states during the early stages of the project because both play a role in team satisfaction and potency.

Although the findings did not indicate that perceptions of team processes (T1) had a greater impact on the outcome variables compared to perceptions of team emergent states (T1), team processes did have an effect on team satisfaction and potency. In addition to understanding which mechanisms have the largest effect on team outcomes, it is important to understand which mechanisms have significant relationships with the outcomes. In other words, even those that have smaller effects are a valuable piece of the puzzle. Team processes have the potential to influence team outcomes earlier in the duration of the team project because they come into play quicker than team emergent states which take time to surface, however, there might not have been enough time for team members to observe the processes before the midterm (time one). In other words, the lack of support for this hypothesis could be attributed to the duration of time before measures of perceptions of team processes were collected. Thus, there still may be a certain timeframe for when these effects start occurring, and if more time had elapsed, then the effects of the perceptions of these processes would have had greater influence on team outcomes.

The results of the multiple linear regressions examining the relationship between time two measures indicated that there was a significant positive relationship between perceived team satisfaction and perceived coordination, trust, and psychological safety, respectively. Similarly, there was a significant positive relationship between perceived team potency with perceived coordination and trust, respectively. There was partial

support for Hypothesis 4a and 4b such that perceptions of both team emergent states (trust and psychological safety) at time two had a significant positive relationship with perceived team satisfaction (T2), and trust (T2) was positively related to team potency (T2). Trust (T2) had the largest effect on both outcomes (T2) out of all team processes and emergent states. However, coordination (T2), a team process, also had a significant effect on both outcomes (T2) and one that was larger than psychological safety (T2). The result's indication of coordination (T2) as a significant predictor of perceived team satisfaction and team potency suggests that this is an important team process, one that has an impact throughout the duration of a team project. The significant effect of perceived team trust (T2) and team psychological safety (T2) on team satisfaction (T2) is notable and suggests that as these shared perceptions emerge over time, they have an influence on perceived team satisfaction. Therefore, as time progresses, team members should be aware of the impact that coordination, trust, and psychological safety have on team satisfaction and potency. By pinpointing which mechanisms are affecting team dynamics, instructors can check in with teams that may have previously had lower scores on perceived coordination, trust, and psychological safety to determine if these mechanisms are undermining team progress.

Similar to the idea that perceptions of team emergent states at time two would have a larger effect on team outcomes at time two compared to team processes, the notion that perceptions of team emergent states at time two would have a larger effect on team outcomes compared to team emergent states at time one was tested. The findings indicate that team trust and psychological safety (T2) are significantly and positively related to

perceived team satisfaction (T2). These results provide support for Hypothesis 5a. This suggests that as time progresses and shared perceptions of trust and psychological safety emerge, there is a significant effect on perceived team satisfaction and potency. Similar to the lessons learned from the findings for Hypothesis 4, it is necessary to understand the impact of team emergent states on team outcomes. Additionally, it is critical to examine these mechanisms longitudinally to account for the temporal aspects of trust and psychological safety.

The topic modeling allowed for efficient analysis of a large amount of team feedback data. Using the topic model, it was possible to identify the number of topics being discussed; the present study examined three candidate models for both the time one and time two data. The topic model allowed for the identification of key terms that comprised different topics within each respective model. Additionally, the results indicated that the topic model successfully assigned documents to particular topics (recall the top responses). The use of visualizations throughout each step aided in understanding the details and interpretation of topics. Each visualization provided more insight as to what was being discussed in the feedback and how certain concepts resulted in a particular theme. Although the topic model did not generate topics that could be easily labeled by a human, the results provided insight to the number and content of topics. A valuable lesson learned from the application of a topic model to student feedback comments is that this technique is limited in its ability to generate easily discernible topics when provided short, unsophisticated feedback.

The present study provides a detailed explanation of how to build an STM of open-ended assessment responses. The application of topic modeling serves as a demonstration of this advanced statistical method to inspire future researchers to utilize this type of approach to qualitative analysis. The continued use of topic models will provide further insight into capabilities of this NLP technique to guide researchers' decisions for how and when topic modeling should be used.

#### **Practical Implications**

The findings indicate that perceptions of role clarity were positively related to perceived team potency. Additionally, perceived team satisfaction was positively related to cooperative conflict management and trust. These findings illustrate the various team processes and emergent states that affect perceived team satisfaction and team potency. It is important to understand how not only the actions and interactions affect team outcomes, but also how team members' perceptions of these dynamics play a significant role.

The findings related to the impact of each predictor on team satisfaction and team potency at time one provided further insight into how these aspects of teamwork are related. There were significant relationships between perceptions of team satisfaction and strategy formulation, coordination, and trust, and significant relationships between perceptions of team potency and perceived role clarity and trust. Therefore, there are practical implications for emphasizing the importance of these team processes and emergent states when students are beginning to work in teams for the course project. This emphasis can continue throughout the duration of the project, but it is helpful to provide

insight at the start. The course instructors would benefit from receiving team development training, so that they can gain an understanding of how team mechanisms like team processes and emergent states influence team outcomes. The knowledge from team skills training could then be passed along to students before they begin their team projects.

The results of the explorations of relationships between perceptions of team processes and team emergent states and perceived team satisfaction and potency at time two indicated there are several significant predictors of these outcomes. Namely, perceived coordination, trust, and psychological safety for perceived team satisfaction, and perceived coordination and trust for perceived team potency. The implication provided by the knowledge of this impact on perceived team satisfaction and potency at the end of the project is that this information can be used to provide instructors with the recommendation to check in (or collect feedback) during the earlier stages of the project to determine if teams are having any issues pertaining to trust, coordination, or psychological safety. Similarly, the findings that indicated perceptions of certain team emergent states in the long run can be used to inform both instructors and team members of the aspects of teamwork that could be allowing teams to excel or hindering their progress.

## Limitations

There are a few limitations of the present study that ought to be acknowledged. An important contextual constraint to note is that the duration for team projects was
influenced directly by the length of the academic semester. The semesters in which the project data was collected were approximately five months long (i.e., Fall and Spring terms). Thus, the student teams had a relatively brief period of time to work together. If the project duration had been longer, then data could have been collected at more than two timepoints. It is possible that this limitation contributed to some of the insignificant findings. Perhaps with more time, given that it takes time for team processes to unfold and shared perceptions to emerge, the effects of perceptions of team processes and team emergent states on perceptions of team satisfaction and team potency would have been better illustrated.

Another noteworthy limitation is that the present study used self-report measures for all variables. There are drawbacks to relying solely on self-report measures including susceptibility to the influence of social desirability (Paulhus, 2018) and faking (Donovan et al., 2003). I believe it is important to know and understand how team member perceptions influence team performance and dynamics. Varying perceptions demonstrate that despite being a part of the same team, each member has their own unique experience. Thus, there is value in using self-report measures, but collecting objective measures would also be helpful.

The lack of potential generalizability of this sample can also be considered a limitation. The sample of undergraduate student teams, specifically engineering students, might not be a representative sample that can be generalized to student teams working in other disciplines or to other teams at a professional level. Despite this limitation, research has acknowledged that student teams collaborating within educational environments (e.g.,

classroom, research lab) offer a valuable research context for examining group dynamics longitudinally because researchers can regulate data acquisition and access (Cronin et al., 2011).

This study could have benefited from having an objective measure of team performance. However, I was unable to obtain students' grades for their team project. Future research ought to include an objective performance measure to use as an outcome variable. There could be interesting conclusions drawn from explorations of relationships between team processes and emergent states and objective team performance (e.g., team performance scores for teams with low/high levels of perceived lack of role clarity and coordination).

Missing data typically interferes with data analysis and can be considered a limitation of research studies. However, there are data imputation methods that can be used to overcome the limitations of missing data for data analysis. The present study utilized a multiple imputation method, which is a technique for analyzing data with missing values (Sinharay et al., 2001). This method generated multiple data sets which were then analyzed using the functions in the Hmisc R package. The output provides parameter estimates and standard errors that account for the uncertainty that exists due to missing data values (Sinharay et al., 2001). While multiple imputation is advantageous over single imputation, it would be better to not have to impute any data. However, it is worthwhile to recall that only 9.3% of the values were missing from the original data set. From a logistical standpoint, using the Hmisc package led to the creation of R objects that could not be used within certain summary or plotting functions (e.g., *summ* function in

the jtools package) which added significant time to the interpretation of results. Advances in the statistical packages will hopefully negate these challenges for future researchers.

There were a few limitations of using an STM. Compared to the ease with other topic models, it is more difficult to use bigrams or trigrams in an STM. To specify the inclusion of bigrams the user must use different preprocessing functions in other R packages. These other functions generate objects that must then be converted to objects that can be used in the stm package's functions (e.g., a document-term matrix (DTM)).

Another limitation of the topic modeling is a consequence of the quality of data. The present study used student feedback which resulted in relatively short comments. This could be a result of students being hesitant (or perhaps unable) to provide sophisticated feedback about their team experience. Having a collection of short text to input likely affected the resulting topics in the candidate models. There is a package for biterm topic modeling for short text (BTM), however, this generates a model based on the biterm occurrences in a corpus which is different from STM or LDA that model word occurrences. As the machine learning field continues to advance, there will be more and better tools available for analyzing short texts.

The use of an unsupervised model could be considered a limitation of the present study. The unsupervised model was used since the topic modeling was used to explore what contextual factors or other aspects of teamwork were discussed in the team feedback. Thus, the model was not trained based on an existing set of topics to generate specific team processes or emergent states as topics. However, this could be done in future research.

The topic model does not automatically generate topic labels. This is where the human aspect of topic modeling comes into play. However, the labeling of topics is easier conceptually than in practice. Previous research has acknowledged that topics generated by topic models are often not easily interpreted (Sievert & Shirley, 2014) and that it is difficult to characterize individual topics (Ramage et al., 2009). Despite challenges with generating topic labels, the various tools utilized to explore the topic content were able to provide valuable insights into the topics generated from team feedback.

#### **Directions for future research**

There are several avenues for future research to continue the advancement of team research. There ought to be further research that includes other team processes and team emergent states to explore team members' perceptions of these additional contributing factors. There are important team mechanisms that underlie team dynamics that were not included in the present study. Researchers should take team factors such as team composition and organizational context into consideration when exploring team members' perceptions of different elements of teamwork to be sure to include relevant measures. For example, a researcher assessing perceived team satisfaction in virtual teams might benefit from including items that capture information about communication tools (e.g., email, Microsoft Teams, Zoom), virtual meeting procedures, and time zone management to collect information that is relevant to factors that influence team satisfaction in a virtual context.

Conducting longitudinal studies would contribute to the advancement of understanding team dynamics. Time is a fundamental element of teamwork and should be

incorporated into research study designs in a way that allows the researcher to gain insight into the role that time plays in team dynamics. Time shapes how teams organize, collaborate, and adapt to achieve their objectives. Teams operate within temporal constraints including project timelines, meeting schedules, and deadlines. Thus, time influences various aspects of teamwork (e.g., planning, coordination, conflict) and is important to consider when exploring the relationships between team processes and outcomes. Although the present study was longitudinal, it would have been beneficial to have had a longer project duration that would have allowed for data collection at more time points. If there was more time, then the influence of a team-level property (e.g., trust) would have had time to shape the individual interactions from which it originated, and additional data could have been collected to examine this recursive influence on individual team members' interactions (Cronin et al., 2011).

Future research ought to be conducted to determine the extent to which perceptions of strategy formulation, role clarity, team monitoring and backup, goal progression, coordination, cooperative conflict management, trust, and psychological safety affect perceptions of other team outcomes such as team creativity or team cohesion. As noted in the limitations of the present study, there were only self-report measures included, but future research would benefit from including objective assessments of teamwork such as observational coding or social network analysis (SNA). Previous research using SNA has shown that a co-evolution of network ties and team perceptions exists (Schulte et al., 2010). Mathieu and colleagues (2017) noted that SNA is a fruitful avenue for future team research. As a follow up to the present study, I have

considered using SNA data that I collected in a parallel project to conduct exploratory analyses to examine the structure and dynamics of social relationships within teams. The use of objective measures along with subjective in future research is warranted because to understand a team phenomenon one must understand the difference between an objective construct and the perceptions of that construct.

Incorporating innovative use of advanced statistical methods like NLP is another avenue that is ripe for future research. The present study applied topic modeling methods to analyze open-ended feedback comments. This approach was intentionally selected to uncover hidden themes within the qualitative data. Future research could use the results of a text analysis to inform what constructs ought to be measured that might not have previously been considered. There are several other types of NLP that could be used to quickly analyze large amounts of valuable qualitative data in a way that would assist researchers' ability to efficiently explore context information. These include but are not limited to named entity recognition, sentiment analysis, summarization, and text classification. Future research could use topic modeling to assist researchers in the qualitative coding process. For example, if there is a codebook that was developed based on human coding of qualitative data collected for a project, then the research could use a supervised topic model to evaluate the qualitative survey data. The topic model could be leveraged to explore how themes from qualitative data map onto the codebook categories. The research could compare the topic model results to the human coding of the same set of qualitative data to gauge the effectiveness of the topic model. It is advantageous for

future researchers to utilize qualitative data, but it is critical that there is appropriate understanding and application of any type of advanced NLP to analyze such data.

### Conclusion

Teams are an increasingly integral part of how students are educated. This is in part due to the growing reliance on groups and teams as a key component of how organizations operate. Therefore, the advancement in a comprehensive understanding of how teams function to achieve goal attainment is necessary. The objective inputs to a team project impact team outcomes, but the perceptions of team members actions and interactions also have an important role. The present study examined the effects of team members' perceptions of several team processes and emergent state on perceptions of team satisfaction and potency. This research highlights strategy formulation, role clarity, coordination, team monitoring and backup, trust, and psychological safety as aspects of teamwork for instructors and students to focus on for future team efforts. Being aware that perceptions of these team processes and emergent states can influence team outcomes is an important first step in making adjustments to improve team project experiences and outcomes. The findings suggest that certain mechanisms require more time to emerge and subsequently impact team members' perceived satisfaction and potency. In addition to shedding light on differences between the effects perceptions of team processes and team emergent states at differing stages of a group project, the present study demonstrates an innovative application of NLP to qualitative team feedback. Lastly, practical implications revealed by this project and suggestions for future research were provided.

### APPENDICES

### Table 1.

### Scale reliabilities

Construct	Scale	Authors	Items	Cronbach's α T1	Cronbach's α T2
Strategy formulation	Team process scale	Mathieu et al. (2020)	3	0.73	0.77
Role clarity	Role conflict and ambiguity scale	Rizzo et al. (1970)	3	0.79	0.78
Cooperative conflict management	Cooperative approach to conflict scale	Tjosvold (1985)	3	0.79	0.84
Team monitoring & backup	Team process scale	Mathieu et al. (2020)	3	0.75	0.77
Monitoring goal progression	Team process scale	Mathieu et al. (2020)	3	0.83	0.84
Coordination	Team process scale	Mathieu et al. (2020)	3	0.85	0.87
Trust	Trustworthy scale	Pearce et al. (1992)	3	0.88	0.89
Psych safety	Team psychological safety scale	Edmondson (1999)	7	0.71	0.79
Team satisfaction	Team player inventory	Kline (1999)	5	0.90	0.90
Team potency	Potency scale	Guzzo et al. (1993)	4	0.86	0.88

## Table 2.

*Hypothesis 1 regression estimates* 

	H1
Strategy formulation	-0.00 (0.13)
Role clarity	0.40 *** (0.11)
Team monitoring & backup	0.17 (0.17)
Monitoring goal progression	-0.13 (0.12)
Coordination	0.31 * (0.12)
N. obs.	114
$R^2$ [Adj. $R^2$ ]	0.46 [0.43]

Note. Linear regression on perceived team potency. \*\*\*  $p < 0.001; \;$  \*\*  $p < 0.01; \;$  \* p < 0.05

# Table 3.

Hypothesis 2 regression estimates

	H2
Cooperative conflict mgmt	0.66 *** (0.12)
Trust	0.33 * (0.13)
Psychological safety	-0.39 * (0.18)
N. obs.	114
$R^2$ [Adj. $R^2$ ]	0.45 [0.44]

Note. Linear regression on perceived team satisfaction. \*\*\*  $p < 0.001; \ ** \ p < 0.01; \ * \ p < 0.05$ 

# Table 4.

	Full	Reduced_1	Reduced_2
Strategy formulation	0.23 * (0.09)	0.26 * (0.10)	
Role clarity	0.03 (0.08)	0.11 (0.09)	
Cooperative conflict mgmt	0.12 (0.10)	0.29 ** (0.10)	
Team monitoring & backup	-0.22 (0.12)	-0.15 (0.14)	
Monitoring goal progression	0.03 (0.08)	0.00 (0.09)	
Coordination	0.28 ** (0.10)	0.33 ** (0.11)	
Trust	0.49 *** (0.10)		0.85 *** (0.08)
Psychological safety	0.04 (0.13)		0.13 (0.13)
N. obs.	114	114	114
$R^2$ [Adj. $R^2$ ]	0.68 [0.66]	0.60 [0.58]	0.54 [0.53]

Hypothesis 3a model 1-3 regression estimates

*Note.* Linear regression on perceived team satisfaction. \*\*\* p < 0.001;\*\* p < 0.01;\* p < 0.05

## Table 5.

	Full	Reduced_1	Reduced_2
Strategy formulation	-0.05 (0.10)	-0.01 (0.11)	
Role clarity	0.32 *** (0.09)	0.39 *** (0.09)	
Cooperative conflict mgmt	0.07 (0.11)	0.07 (0.11)	
Team monitoring & backup	0.30 * (0.14)	0.29 (0.15)	
Monitoring goal progression	-0.07 (0.09)	-0.14 (0.09)	
Coordination	0.14 (0.11)	0.23 * (0.11)	
Trust	0.33 ** (0.11)		0.82 *** (0.09)
Psychological safety	-0.41 ** (0.15)		-0.25 (0.15)
N. obs.	114	114	114
$R^2$ [Adj. $R^2$ ]	0.61 [0.58]	0.55 [0.52]	0.42 [0.41]

Hypothesis 3b model 1-3 regression estimates

*Note.* Linear regression on perceived team potency. \*\*\* p < 0.001; \*\* p < 0.01; \* p < 0.05

## Table 6.

	Full	Reduced_1	Reduced_2
Strategy formulation	0.20 (0.13)	0.15 (0.14)	
Role clarity	-0.18 (0.11)	-0.10 (0.13)	
Cooperative conflict mgmt	0.08 (0.13)	0.34 * (0.14)	
Team monitoring & backup	0.08 (0.12)	0.24 (0.13)	
Monitoring goal progression	-0.15 (0.10)	-0.15 (0.11)	
Coordination	0.36 *** (0.10)	0.57 *** (0.10)	
Trust	0.60 *** (0.12)		0.93 *** (0.07)
Psychological safety	0.35 ** (0.13)		0.47 *** (0.13)
N. obs.	114	114	114
$R^2$ [Adj. $R^2$ ]	0.79 [0.77]	0.72 [0.70]	0.73 [0.73]

Hypothesis 4a model 1-3 regression estimates

*Note.* Linear regression on perceived team satisfaction (T2). \*\*\* p < 0.001; \*\* p < 0.01; \* p < 0.05

## Table 7.

	Full	Reduced_1	Reduced_2
Strategy formulation	0.15 (0.11)	0.06 (0.12)	
Role clarity	0.06 (0.10)	0.14 (0.11)	
Cooperative conflict mgmt	-0.14 (0.12)	-0.05 (0.12)	
Team monitoring & backup	0.06 (0.11)	0.22 (0.11)	
Monitoring goal progression	0.14 (0.09)	0.13 (0.09)	
Coordination	0.28 ** (0.09)	0.41 *** (0.09)	
Trust	0.49 *** (0.11)		0.93 *** (0.07)
Psychological safety	-0.27 * (0.12)		-0.16 (0.13)
N. obs.	114	114	114
$R^2$ [Adj. $R^2$ ]	0.77 [0.75]	0.72 [0.70]	0.67 [0.67]

Hypothesis 4b model 1-3 regression estimates

*Note.* Linear regression on perceived team potency (T2). \*\*\* p < 0.001; \*\* p < 0.01; \* p < 0.05

## Table 8.

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Hypothesis	<u></u>	regression	estimates
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	H5a	H5b
Trust (T1)	0.06 (0.11)	-0.02 (0.10)
Psychological safety (T1)	-0.13 (0.15)	-0.05 (0.14)
Trust (T2)	0.88 *** (0.11)	0.93 *** (0.09)
Psychological safety (T2)	0.48 ** (0.17)	-0.11 (0.15)
N. obs.	114	114
$R^2$ [Adj. $R^2$ ]	0.67 [0.66]	0.64 [0.63]

*Note.* Linear regression on perceived team satisfaction (T2) and team potency (T2). \*\*\* p < 0.001; \*\* p < 0.01; \* p < 0.05

# Table 9.

Means, standard deviations, and correlations with confidence intervals

Variable	М	SD	1	2	3	4	5	6	7	8	9	10
1. Strategy form. T1	4.34	0.36										
2. Role clarity T1	4.35	0.41	.69**									
			[.58, .78]									
3. Cooperative CM T1	4.48	0.35	.57**	.55**								
			[.43, .68]	[.40, .66]								
4. Team MB T1	4.34	0.34	.71**	.66**	.74**							
			[.60, .79]	[.55, .76]	[.64, .81]							
5. Monitoring Goal T1	4.10	0.45	.72**	.66**	.54**	.73**						
			[.62, .80]	[.54, .75]	[.39, .66]	[.63, .80]						
6. Coordination T1	4.34	0.47	.70**	.68**	.72**	.82**	.72**					
			[.59, .78]	[.57, .77]	[.62, .80]	[.74, .87]	[.62, .80]					
7. Trust T1	4.62	0.37	.53**	.61**	.65**	.66**	.56**	.70**				
			[.38, .65]	[.47, .71]	[.53, .74]	[.54, .75]	[.42, .68]	[.59, .78]				
8. Psych. Safety T1	5.44	0.20	.24*	.17	.45**	.36**	.21*	.22*	.27**			
			[.06, .40]	[02,.34]	[.29, .59]	[.18, .51]	[.03, .38]	[.04, .39]	[.09, .43]			
9. Potency T1	4.36	0.36	.57**	.60**	.52**	.65**	.54**	.69**	.62**	.04		
			[.44, .69]	[.47, .70]	[.38, .65]	[.53, .74]	[.39, .66]	[.58, .78]	[.49, .72]	[14,.23]		

10. Satisfaction T1	4.46	0.42	.56**	.61**	.60**	.61**	.60**	.72**	.79**	.28**	.62**	
			[.42, .68]	[.48, .71]	[.47, .71]	[.48, .72]	[.47, .71]	[.62, .80]	[.71, .85]	[.10, .44]	[.50, .72]	
11. Strategy form T2	4.43	0.34	.58**	.50**	.52**	.60**	.50**	.56**	.47**	.22*	.46**	.46**
			[.45, .69]	[.35, .63]	[.37, .64]	[.47, .70]	[.35, .62]	[.42, .67]	[.31, .60]	[.04, .39]	[.31, .60]	[.30, .60]
12. Role Clarity T2	4.50	0.34	.57**	.63**	.53**	.54**	.52**	.52**	.49**	.21*	.48**	.41**
			[.44, .69]	[.51, .73]	[.38, .65]	[.40, .66]	[.37, .64]	[.37, .64]	[.34, .62]	[.03, .38]	[.33, .61]	[.24, .55]
13. Cooperative CM T2	4.52	0.41	.37**	.38**	.52**	.54**	.38**	.53**	.48**	.30**	.44**	.47**
			[.20, .52]	[.21, .53]	[.37, .64]	[.40, .66]	[.21, .52]	[.38, .65]	[.33, .61]	[.12, .46]	[.27, .57]	[.31, .60]
14. TeamMB T2	4.43	0.42	.51**	.44**	.50**	.61**	.49**	.56**	.44**	.24*	.45**	.41**
			[.36, .63]	[.28, .58]	[.35, .63]	[.48, .71]	[.34, .62]	[.42, .68]	[.28, .58]	[.05, .40]	[.29, .58]	[.25, .55]
15. Monitoring Goal T2	4.29	0.43	.58**	.52**	.46**	.61**	.59**	.52**	.44**	.21*	.47**	.39**
			[.45, .69]	[.37, .64]	[.30, .59]	[.48, .71]	[.45, .70]	[.37, .64]	[.27, .57]	[.03, .38]	[.31, .60]	[.22, .54]
16. Coordination T2	4.44	0.47	.49**	.44**	.50**	.55**	.43**	.59**	.47**	.23*	.46**	.46**
			[.34, .62]	[.28, .58]	[.34, .62]	[.41, .67]	[.26, .57]	[.45, .69]	[.31, .60]	[.05, .40]	[.31, .60]	[.30,.59]
17. teamTrust_T2	4.60	0.45	.43**	.44**	.53**	.56**	.46**	.56**	.54**	.22*	.50**	.53**
			[.26, .57]	[.28, .58]	[.38, .65]	[.42, .67]	[.30, .59]	[.42, .67]	[.40, .66]	[.04, .39]	[.35, .63]	[.38, .65]
18. Psych Safety T2	5.45	0.23	.26**	.19*	.40**	.36**	.21*	.36**	.27**	.36**	.21*	.36**
			[.08, .42]	[.00, .36]	[.24, .55]	[.19, .51]	[.02, .38]	[.19, .51]	[.09, .43]	[.19, .51]	[.03, .38]	[.19, .51]

19. Potency T2	4.38	0.39	.51**	.51**	.46**	.57**	.47**	.59**	.50**	.13	.62**	.49**
			[.36, .64]	[.36, .63]	[.30, .60]	[.43, .68]	[.32, .61]	[.45, .70]	[.35, .62]	[06, .31]	[.49, .72]	[.34, .62]
20. Satisfaction T2	4.40	0.52	.46**	.43**	.56**	.54**	.43**	.56**	.52**	.31**	.49**	.62**
			[.30, .59]	[.26, .57]	[.42, .68]	[.39, .66]	[.27, .57]	[.42, .67]	[.37, .64]	[.14, .47]	[.34, .62]	[.49, .72]

11	12	13	14	15	16	17	18	19

.79**	.69**	.86**				
[.71, .85]	[.58, .78]	[.80, .90]				
.79**	.72**	.66**	.78**			
[.70, .85]	[.62, .80]	[.54, .75]	[.70, .85]			
.82**	.71**	.83**	.82**	.75**		
[.75, .87]	[.60, .79]	[.76, .88]	[.75, .87]	[.66, .82]		
.72**	.66**	.88**	.84**	.67**	.86**	
[.62, .80]	[.54, .75]	[.84, .92]	[.78, .89]	[.56, .76]	[.80, .90]	
.42**	.31**	.52**	.44**	.37**	.52**	.51**
[.26, .56]	[.14, .47]	[.38, .65]	[.28, .58]	[.20, .52]	[.38, .65]	[.36, .63]

[.66, .82]

.75\*\*

[.66, .82]

.64\*\*

[.52, .74]

.75\*\*

.75**	.67**	.71**	.74**	.71**	.77**	.77**	.37**	
[.66, .82]	[.55, .76]	[.61, .79]	[.64, .81]	[.61, .79]	[.68, .84]	[.69, .84]	[.20, .52]	
.68**	.55**	.81**	.72**	.57**	.80**	.86**	.57**	.74**
[.57, .77]	[.41, .67]	[.74, .87]	[.62, .80]	[.44, .69]	[.73, .86]	[.81, .90]	[.43, .68]	[.64, .81]

*Note. M* and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014). \* indicates p < .05. \*\* indicates p < .01.

## Table 10.

Variable	Group ID	rwg.lindell	Group size
Strategy formulation			
	40253.007	0.05555556	3
	49269.009	0.1944444	4
	49269.01	0.38888889	3
	77203.003	0.38888889	3
	56224.003	0.4444444	3
	69956.007	0.45833333	4
	84290.007	0.45833333	4
	49269.003	0.47222222	4
	85244.004	0.5	3
Role clarity			
	40253.007	-0.88888889	3
	85244.004	-0.38888889	3
	40253.003	-0.08333333	4
	56224.003	0.05555556	3
	84221.004	0.16666667	3
	49269.009	0.20833333	4
	40253.004	0.22222222	3
	49269.007	0.27777778	4
	49269.002	0.38888889	3
	77203.007	0.38888889	3
	77203.01	0.38888889	3
	77204.007	0.40277778	4
	64671.003	0.4444444	3
	69990.001	0.47222222	4

Teams that did not meet aggregation criteria for Time 1

	64286.005	0.5	3
	77205.001	0.5	3
Cooperative conflict mgmt			
	85244.004	-0.7777778	3
	77204.007	0.2083333	4
	85244.003	0.2222222	3
	69917.005	0.3333333	3
	64286.005	0.3888889	3
	69956.007	0.4583333	4
	40253.004	0.5	3
	64286.003	0.5	3
	69990.001	0.5	4
Team monitoring & backup			
	64286.005	0	3
	85244.004	0.2222222	3
	77204.007	0.2916667	4
	40253.007	0.3888889	3
	49269.002	0.3888889	3
	69990.001	0.4166667	4
	84290.007	0.4583333	4
	84221.002	0.4722222	4
Monitoring goal progression			
	40253.007	-0.22222222	3
	85244.004	-0.22222222	3
	77205.001	-0.11111111	3
	49269.009	0.02777778	4
	85244.003	0.05555556	3
	77205.003	0.1944444	4
	77204.002	0.20833333	4

	49269.003	0.25	4
	56224.003	0.27777778	3
	64671.003	0.27777778	3
	69917.005	0.33333333	3
	69960.002	0.38888889	3
	64671.001	0.38888889	3
	56223.006	0.5	4
	77205.005	0.5	3
Coordination			
	85244.004	-0.5	3
	40253.007	-0.22222222	3
	84290.007	-0.125	4
	69960.002	0	3
	77204.007	0.09722222	4
	56224.003	0.16666667	3
	85244.003	0.22222222	3
	85244.001	0.27777778	3
	84219.004	0.29166667	4
	40253.004	0.33333333	3
	69956.008	0.36111111	4
	64286.003	0.38888889	3
	64671.001	0.38888889	3
	56223.008	0.38888889	3
	56223.003	0.5	3
	69917.005	0.5	3
	77203.003	0.5	3
Trust			
	40253.007	-0.22222222	3
	40253.004	0.05555556	3
•	•	•	•

	85244.004	0.05555556	3
	56222.002	0.08333333	4
	56224.003	0.16666667	3
	77205.001	0.22222222	3
	84221.004	0.5	3
Psychological safety			
	85244.004	0.04761905	3
	69960.007	0.07142857	3
	69917.003	0.19047619	3
	40253.007	0.23809524	3
	69917.001	0.27083333	4
	77205.001	0.30952381	3
	64671.001	0.39285714	3
	84219.002	0.4077381	4
	40253.004	0.44047619	3
	64286.007	0.44047619	3
	69956.002	0.44047619	3
	69960.002	0.48809524	3
	69960.003	0.48809524	4
	77203.007	0.5	3
	85244.003	0.5	3
Team potency			
	64671.001	-0.4166667	3
	69917.001	-0.1458333	4
	40253.007	-0.125	3
	85244.003	0.125	3
	56222.002	0.2395833	4
	84221.004	0.25	3
	49269.009	0.3125	4

	84219.007	0.3333333	3
	77204.011	0.4375	4
	84219.004	0.4583333	4
	56222.004	0.4895833	4
Team satisfaction			
	56224.003	-0.63333333	3
	85244.004	-0.53333333	3
	40253.007	-0.46666667	3
	56223.008	-0.16666667	3
	40253.004	-0.06666667	3
	85244.003	0.03333333	3
	49269.004	0.06666667	3
	56222.002	0.14166667	4
	64671.003	0.16666667	3
	69917.001	0.3	4
	64286.007	0.36666667	3
	56224.001	0.43333333	3
	77205.001	0.43333333	3
	84219.007	0.43333333	3
	85244.001	0.5	3

# Table 11.

Variable	Group ID	rwg.lindell	Group size
Strategy formulation	77205.001	0.05555556	3
	69990.002	0.20833333	4
	49269.009	0.29166667	4
	40253.007	0.5	3
Role clarity			
	69990.002	0.125	4
	64286.005	0.1666667	3
	64671.003	0.2222222	3
	77205.001	0.2777778	3
	64286.002	0.3888889	3
	69917.007	0.444444	3
	77204.009	0.444444	3
	56223.004	0.5	3
	77203.007	0.5	3
Cooperative conflict mgmt			
	64373.003	-0.05555556	3
	64286.002	0	3
	77205.001	0.05555556	3
	64286.005	0.05555556	3
	69990.002	0.125	4
	84290.007	0.45833333	4
	49269.01	0.5	3
	56224.003	0.5	3
	69956.002	0.5	3

Teams that did not meet the aggregation criteria for Time 2

Team monitoring & backup			
	64286.002	-0.38888889	3
	64286.005	-0.38888889	3
	69990.002	-0.04166667	4
	64373.003	0	3
	77205.001	0.27777778	3
	49269.01	0.38888889	3
	49269.008	0.47222222	4
Monitoring goal progression			
	77205.001	-0.1666667	3
	69917.007	0.1666667	3
	69917.001	0.2361111	4
	49269.003	0.2916667	4
	64286.005	0.3888889	3
	84219.004	0.4027778	4
	84219.003	0.4722222	4
	49269.002	0.5	3
	56223.004	0.5	3
	69917.005	0.5	3
	69956.008	0.5	4
	69960.002	0.5	3
	77203.003	0.5	3
	77205.005	0.5	3
Coordination			
	69990.002	-0.25	4
	64286.005	0	3
	64373.003	0.05555556	3
	77205.001	0.11111111	3
	69960.005	0.36111111	4
	•	•	•

	49269.01	0.38888889	3
	49269.009	0.41666667	4
	49269.004	0.5	3
	77203.003	0.5	3
Trust			
	64373.003	-0.444444	3
	49269.01	0.1111111	3
	64286.002	0.2222222	3
	77205.001	0.2777778	3
	64286.005	0.3888889	3
	56222.002	0.4722222	4
	56223.008	0.5	3
	64671.003	0.5	3
Psychological safety			
	64286.004	-0.18154762	4
	64286.002	-0.14285714	3
	84219.006	-0.10714286	4
	77204.009	-0.08333333	3
	64286.005	-0.04761905	3
	56224.003	-0.01190476	3
	85244.003	-0.01190476	3
	77205.001	0	3
	77203.01	0.03571429	3
	64286.011	0.12797619	4
	69990.002	0.35416667	4
	56223.001	0.36904762	3
	84290.007	0.39285714	4
	77204.001	0.41666667	3
	69990.001	0.46130952	4

	56222.002	0.46428571	4
	56222.003	0.46428571	3
	77205.002	0.46428571	4
	84221.005	0.47619048	3
	56224.002	0.48214286	4
	69960.005	0.49702381	4
Team potency			
	84221.004	-0.41666667	3
	64671.001	0.08333333	3
	77205.001	0.20833333	3
	49269.004	0.33333333	3
	69956.004	0.40625	4
	64671.003	0.45833333	3
	69917.001	0.46875	4
	64373.003	0.5	3
Team satisfaction			
	64373.003	-0.9	3
	77205.001	-0.43333333	3
	77203.003	-0.26666667	3
	40253.007	-0.13333333	3
	56224.003	-0.03333333	3
	69917.001	0.05833333	4
	69990.002	0.09166667	4
	64286.005	0.1	3
	69960.002	0.16666667	3
	56223.003	0.3	3
	64671 003	0.33333333	3
	04071.005	0.00000000	
	49269.01	0.366666667	3
	49269.01 49269.004	0.36666667 0.4	3 3

77203.002	0.4	3
56222.002	0.40833333	4
84221.002	0.40833333	4
77204.003	0.45833333	4
77203.01	0.46666667	3
84219.007	0.46666667	3
84219.004	0.5	4

## Table 12.

## Count of teams' data points removed per variable

Variable	# of teams removed at Time 1	# of teams removed at Time 2
Strategy formulation	9	4
Role clarity	16	9
Cooperative conflict mgmt	9	9
Team monitoring & backup	8	7
Monitoring goal progression	15	14
Coordination	17	9
Trust	7	8
Psychological safety	15	21
Potency	11	8
Satisfaction	15	20

### Figure 1.

Screenshot of LDAvis tool for the 8-topic solution for the time 1 STM.



### Appendix A

### ChatGPT prompt and generated text for time 1 STM topic labels

### **Prompt:**

You have just conducted a topic model. You have extracted this information from the results: Most frequent words for each topic are as follows. For topic 1: able, manner, timely, quality, ideas, tasks, effectively. For topic 2: one, help, needed, class, another, outside, tasks, effort, lab. For topic 3: like, feel, can. For topic 4: together, well, get, overall, works, know, can, complete, communicate, communication. For topic 5: good, done, job, think, time, better, getting, things, assignments, communicating. For topic 6: think, need, design, final, time, conceptual, report, presentation, will, phase. For topic 7: group, members, deadlines, meeting, always, member, others. For topic 8: great, working, project, job, everyone, far, worked, believe, also. The top 10 exclusive words for each candidate model were extracted. The exclusive words for the topics in the model with 8 topic solutions are as follows in order of descending frequency. For topic 1: manner, timely, quality, high, ideas, communicated, able, effectively, new, product. For topic 2: another, person, effort, among, example, given, helped, responding, understanding, roles. For topic 3: see, late, ever, less, respectful, responsibilities, like, feel, benefit, wait. For topic 4: works, efficiently, together, appreciate, complete, well, overall, know, communicate, get. For topic 5: getting, good, done, everyones, assignments, sooner, things, date, better, job. For topic 6: final, conceptual, phase, guys, enjoy, items, need, design, turned, presentation. For topic 7: deadlines, weight, difficult, issue, positive, within, meeting, setting, rest, allow. For topic 8: great, yall, say, coming, working, worked, project, presenting, assignment, designs. I extracted key responses from topics within each candidate model. Excerpts from examples of top responses for Topic 1 in the model with 8 solutions include, "When we needed information regarding the other person's specialty we were able to provide them with it in a timely manner", "We did well with organization of project work and team meetings as well as general time management", "All project work is designated and completed in an efficient and timely manner, and this work is back-checked for completeness and accuracy before submission". Excerpts from the top responses for Topic 4 in the model with 8 solutions include, "Team works well together, sometimes we get off topic and lose productivity, but that's more because we work really well together, not because we are in conflict", "I am very happy with our progress and the way we work together", "I look forward to continuing to work together in the future. I know this is a reliable group". Please provide labels for the 8 topics based on this information.

### **ChatGPT:**

Based on the information provided, here are the suggested labels for each of the 8 topics:

Efficiency and Quality Assurance: This topic seems to revolve around timely and effective completion of tasks, ensuring quality and generating new ideas. The excerpts highlight the ability to provide information in a timely manner, efficient organization of project work, and back-checking for completeness and accuracy.

Collaborative Effort and Support: This topic focuses on the collaborative efforts within the team, offering help, and understanding each other's roles. Excerpts mention helping each other, understanding roles, and providing examples of collaboration.

Respectful Communication and Responsibilities: This topic emphasizes communication and respect within the team, including being respectful of each other's time and responsibilities. Excerpts mention waiting, being late, and respecting each other's responsibilities.

Team Dynamics and Productivity: This topic highlights the dynamics within the team and its impact on productivity. Excerpts discuss working well together, occasional distractions, and overall satisfaction with the team's progress.

Task Management and Progress Tracking: This topic centers around managing tasks efficiently and tracking progress. Excerpts mention completing assignments, improving efficiency, and staying on track with deadlines.

Project Planning and Execution: This topic relates to planning and executing project phases effectively. Excerpts discuss finalizing designs, enjoying the process, and preparing presentations.

Deadline Management and Issue Resolution: This topic addresses managing deadlines and resolving issues effectively. Excerpts mention setting deadlines, addressing difficult issues, and maintaining a positive attitude.

Positive Feedback and Team Motivation: This topic focuses on providing positive feedback and maintaining team motivation. Excerpts highlight satisfaction with progress, looking forward to future work, and acknowledging the reliability of the team.
## Appendix B

### ChatGPT prompt and generated text for time 2 STM topic labels

## **Prompt:**

You have just conducted a topic model. You have extracted this information from the results: Most frequent words for each topic are as follows. For topic 1: got, made, complete, times, part, along, ideas, way. For topic 2: working, enjoyed, everyone, guys, help, always, pressure. For topic 3: semester, really, feel, like, thought, one, yall, best. For topic 4: time, completing, others, communicated, excellent, members, completed, class, quality, tasks. For topic 5: project, believe, overall, finished, member, throughout. For topic 6: well, together, worked, great, job, done, communicating, manner, timely, getting. For topic 7: think, good, job, final, design, overall, report, better, presentation, lot. For topic 8: group, able, get, everyone, done, sure, make, always, needed. The top 10 exclusive words for each candidate model were extracted. The exclusive words for the topics in the model with 8 topic solutions are as follows in order of descending frequency. For topic 1: along, ideas, met, performed, got, turn, made, focused, times, complete. For topic 2: working, guys, pleasure, weight, pulled, efficient, evenly, dynamic, coming, solid. For topic 3: thought, yall, really, feel, ability, decent, keep, lets, thanks, semester. For topic 4: completing, others, completed, meeting, effectively, management, meet, time, hard, quality. For topic 5: individual, success, portions, teammates, weaknesses, contributed, discuss, needs, believe, strengths. For topic 6: manner, well, together, timely, despite, great, worked, responsibilities, communicating, amazing. For topic 7: final, design, report, good, points, lot, think, conceptual, last, minute. For topic 8: finish, need, staying, issue, beginning, stay, submitting, get, glad, make. I extracted key responses from topics within each candidate model. Excerpts from examples of top responses for Topic 1 in the model with 8 solutions include, "All of our discussions were productive especially talking about different viewpoints and ideas", "The team did respond well to all team communications...", "As a team we were able to efficiently complete all presentation slides". These key responses suggest that the team experienced strong communication and a sense of psychological safety that allowed different opinions to be shared. This topic appears to pertain to efficiency resulting from good communication and openness to varying perspectives. Excerpts from examples of top responses for Topic 4 within this model include, "At times our team lacked communication as to what work needed to be done by others and lacked a clear break up of the work..." and "Communication improved over time, but it could still be refined". Please provide labels for the 8 topics based on this information.

# **ChatGPT:**

Based on the provided information, here are suggested labels for each of the 8 topics:

Effective Communication and Collaboration: This topic revolves around productive discussions, effective team communication, and efficient completion of tasks. It emphasizes openness to different viewpoints and ideas within the team.

Team Dynamics and Supportive Environment: This topic focuses on the working atmosphere within the team, emphasizing enjoyment, mutual help, and handling pressure collectively. It reflects a supportive and dynamic team environment.

Reflection on Team Experience and Progress: This topic centers on reflections about the semester's progress and feelings within the team. It includes thoughts on the team's abilities and appreciation for teamwork.

Communication and Task Management: This topic addresses communication issues within the team, particularly regarding task allocation and completion. It highlights the importance of effective communication and task management for successful teamwork.

Individual Contribution and Team Success: This topic discusses individual contributions to the project and their impact on overall team success. It emphasizes understanding teammates' strengths and weaknesses and the importance of collaboration.

Efficient Workflow and Responsibilities: This topic highlights the team's ability to work well together, manage responsibilities, and communicate effectively despite challenges. It reflects on the team's efficient workflow and timely completion of tasks.

Quality of Project Deliverables and Presentation: This topic focuses on the final aspects of the project, including design, report quality, and presentation. It emphasizes the need for improvement and attention to detail in the final deliverables.

Issue Resolution and Project Completion: This topic addresses issues that arose during the project and the team's ability to stay focused and resolve them. It emphasizes the importance of staying on track and addressing issues promptly to ensure project completion.

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