COGNITIVE DIVERSITY AND KNOWLEDGE INTEGRATION IN STUDENT DESIGN TEAMS

by

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Dedicated to Anders.
I promised I wouldn't let you down.
It is my sincerest hope that the quality of and effort
behind this thesis are evidence of my keeping that promise.

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ABSTRACT

This research investigated the influence and relationship of two cognitive diversity frameworks on student design team knowledge integration capabilities and team contribution among seventy-five (75) student teams in Purdue's Tech 120: Design Thinking in Technology course.

When in cognitively diverse teams, students do not effectively integrate the knowledge available to them. Past research results in this area have further demonstrated that students tend to get worse at collaboration as the cognitive differences emerge and are exposed over time. The costs of this lack of collaboration and assimilation of knowledge assets are significant, such as diminished creativity, coordination, and other team performance measures. The purpose of this study then, was to provide student design teams with models or frameworks for visualizing and understanding the cognitive diversity available to them in their team and test the impact these frameworks have on various measures of team effectiveness: knowledge integration, psychological safety, and individual contribution.

Cognitive diversity frameworks in question have been used successfully in various industry and organizational settings. The first, is the FourSight Thinking Profile™. This framework is used to understand one's creative problem-solving preferences and how those preferences (high, neutral, and low) impact group dynamics. The second, is the AEM-Cube®. This framework draws on several theoretical foundations to assess an individua's patterns of thinking and responses to change. Both the FourSight Thinking Profile™ and the AEM-Cube® have shown to help teams in industry settings collaborate (DeCusatis, 2008; Reynolds & Lewis, 2017), but their use in educational settings to solve the knowledge integration and team contribution problem in student teams is untested.

The nearly 470 students in Purdue's TECH 120 course were organized into teams ranging from 3-5 members by their instructors, thus creating a total of 129 teams. The researcher then divided the 129 teams into two fairly equal treatment groups. Each treatment group was given one of two cognitive diversity assessments (FourSight or AEM-Cube) to complete individually, time to review the results, and then asked to create a team charter or contract where students discussed cognitive strengths and weaknesses and how they planned to manage those assets and deficiencies

as they worked on a 4-week long design thinking project. Only 75 teams completed all steps of the treatment (either FourSight or AEM-Cube) and thus were the focus of analysis.

The major conclusions of this study are that while neither the FourSight or AEM-Cube frameworks for cognitive diversity were more effective in raising student knowledge integration capability or overall team contribution, these frameworks did not negatively impact the student experience; high levels of psychological safety were maintained among both more homogeneous teams and those that were more heterogeneous; and higher levels of knowledge integration capabilities and team contribution were achieved by students in varying degrees of diversity of creative problem-solving preferences and strategic agility. While the reason(s) for such high scores for knowledge integration capability, team member contribution, and psychological safety are unknown, the students reported that the processes by which these teams integrated their knowledge assets and solicited the contribution of their team members was both positive and effective.

Further research into the effectiveness of the treatment, the influence of demographic diversities on team functions, and the experience of the 54 student teams that did not complete the treatment are needed to elucidate and understand the findings of this study.

CHAPTER 1. PURPOSE & PROBLEM

1.1 Introduction

> While there are many feel-good arguments in favor of collaboration, the real justification for effective collaboration…can be found in the bottom line. Done right, collaboration makes your firm more successful—in the war for clients, and in the war for talent.
>
> —Gardner, 2017, p. 3

According to Sun Tzu in his classic work, *The Art of War,* there are three ways in which a military leader can bring misfortune to his army. Notably, all three means are rooted in a sort of mindlessness—a disregard for variability and context (Langer, 2014). The first misfortune lies in a leader's ignorance of the army's ability to retreat or advance and commanding the army to obey to either action. The second is in a leader's ignorance of context: leading an army like a kingdom, which Sun Tzu argues are two entirely different forms of leadership. The third is when the leader begins "employing the officers of his army without discrimination, through ignorance of the military principle of adaptation to circumstances. This shakes the confidence of the soldiers" (Giles, 2014, p. 10). Giles (2014) summarizes it this way, "…He [the leader] is not careful to use the right man in the right place" (p. 102).

Far removed from the battlefield, Ed Catmull, the former president of both Pixar Animation and Disney Animation Studios, dealt with this final misfortune in a both painful and triumphant way during the making of *Toy Story 2* (Catmull & Wallace, 2014). The tried and tested team that had made *Toy Story* so successful was deeply focused in making *A Bug's Life*, but the pre-determined deadline for *Toy Story 2* to be completed was quickly approaching. Catmull and other leaders at Pixar, chose a more inexperienced team to work on the animated sequel in hopes that the new team would prove their worth. However, after *A Bug's Life* launched in 1998, the more experienced team took a close look at what was being made by the crew of *Toy Story 2* and evaluated the product as being a "disaster" (Catmull & Wallace, 2014, p. 69). Management made the difficult decision to remove the inexperienced team and hand over the project to the group of earlier successes. In many ways, this would require a complete overhaul of the film's development. Much to the credit of their hard work, however, *Toy Story 2* went on to be acclaimed as one of the "only sequels to outshine the original" and earned a total $500 million at the box office (p. 73-74).

Afterwards, Catmull took time to reflect on what had occurred. He described some of his insights as follows:

> Getting the team right is the necessary precursor to getting the ideas right…Even the smartest people can form an ineffective team if they are mismatched... A good team is made up of people who complement each other. There is an important principle here that may seem obvious, yet—in my experience—is not obvious at all. Getting the right people and the right chemistry is more important than getting the right idea. (p.74)

Catmull had inadvertently learned Sun Tzu's ancient teaching: getting the right people in the right place while creating a positive chemistry is vital to team success. An axiom such as this has led to decades of research into the functions and dysfunctions of teams (Morrison, 2010; Humphrey & Aime, 2014; Lencioni, 2002) and the best formula for team composition (Tshetshema & Chan, 2020; DeCusatis, 2008; Mathieu, Tannenbaum, Donsbach, & Alliger, 2014) to help illuminate the predictors and factors that contribute to successful teams[1] (Shuffler, Diazgranados, Maynard, & Salas, 2018).

Some tenets have guided the research in interesting directions. Of particular mention is the abstraction of diversity as the beginning of novelty, creativity, and innovation. An ecosystem (the American Everglades for example) is stable only because there is a diversity of life that continues to create and innovate upon itself over time. Johnson (2010) argued that such biological phenomena parallels the origination of creativity and innovation in teams and organizations; a diversity of thoughts, ideas, and people in a supportive environment. This compelling argument—made by many and one we accept almost as self-evident—fuels a great deal of academic and public debate on diversity in the workplace.

However, the research in team diversity is burdened with staggering contradictions (Mathieu, Gallagher, Domingo, & Klock, 2019; Srikanth, Harvey, & Peterson, 2016; Mathieu et al., 2014; Tshetshema & Chan, 2020). What level of diversity makes the most impact on team success? Do the effects of diversity wear-off or become emboldened over time? Is there a time when diversity is more hurtful than helpful? These questions and many others are still being asked with incredible variance in the reported findings. Therefore, Sun Tzu's predicted misfortune still

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[1] There is much debate among the usage of "teams" vs. "groups". The definition of teams used for this study will be drawn from Shuffler, Diazgranados, Maynard, & Salas (2018): "Teams are defined as two or more individuals interacting dynamically, interdependently, and adaptively toward a common goal, with each member having a specific role to fill within the boundary of the team" (see also Salas, Dickinson, Converse, & Tannenbaum, 1992).

befalls our organizations and teams because we continue to scratch our heads at how to position the right person in the right place (Humphrey & Aime, 2014).

1.2 Problem

The research into team diversity is at first divided into three distinct types of diversity: surface-level, functional, and deep-level or cognitive. Surface level diversity represents demographic attributes of persons such as their age, race, or gender (Tshetshema & Chan, 2020; Bell, 2007). Functional diversity typically refers to job title or function or area of expertise. Arguably the most complex and most ill-defined is what is described as deep-level or cognitive diversity. This type of diversity represents nearly any unseen characteristic of a person from learning style (Kyprianidou, Demetriadis, Tsiatsos, & Pombortsis, 2012) to personality (DeCusatis, 2008; Beersma, Hollenbeck, Humphrey, Moon, & Conlon, 2003) to preferences for how one tackles certain problems or tasks (Campos, Rubio, Atondo, & Chorres, 2015).

Albeit the research on cognitive diversity is convoluted with divergent definitions, research methodologies, and study findings (Aggarwal & Molinaro, 2013), the unseen characteristics of teams are insatiably desirable sources for study (Srikanth et al., 2016). Two possible reasons to explain this concept's growing research base are, first, the fact that a diversity of thought more closely resembles the biological phenomenon of diversity producing novelty and stability (Bantel & Jackson, 1989; Jehn, Northcraft, & Neale, 1999; Muira & Hida, 2004; Johnson, 2010) and, secondly, because of the salient implications for team composition (Mathieu, Maynard, Rapp, & Gilson, 2008). While surface-level diversity research leads to debates about globalization and multiculturism (Roberson, 2019) and functional diversity on "smart collaboration" or intense knowledge work (Gardner, 2017), cognitive diversity could have an equalizing effect on how we grapple with all types of diversity. For example, the focus of cognitive diversity is on the interplay of "how" one sees, perceives, works, or understands the world rather than on *what* they look like or *what* they know from previous work experience. But getting a consistent model for what type of cognitive diversity really matters, under varying constraints, in specific contexts remains elusive (Humphrey & Aime, 2014; Srikanth et al., 2016). Thus, simultaneously evaluating competing models is of great importance to further advance our understanding of cognitive diversity's role in team performance.

There are more specific challenges for student teams—even beyond the level of diversity that is used to organize them. One such challenge is the problem addressed by this study: students in diverse teams do not integrate the knowledge that is available to them (Dahlin, Weingart, & Hinds, 2005; Klein, Knight, Ziegert, Lim, & Saltz, 2011; Harrison, Price, Gavin, & Florey, 2002) and they get worse at collaboration as deep-level differences are exposed more and more over time (Harrison et al., 2002; Srikanth et al., 2016). The deterioration of collaboration among student team members has been credited to various factors.

The first factor is the inherent complexity of working with diversity. Each human being has unique assets (i.e. social, physical, informational, etc.) that can provide the basis for conscious linking and leveraging processes with the aim of innovation (Haines, 2015; Gardner, 2017; Christensen, 1996). However, first understanding who has what available assets can be challenging to new teams (Morrison, Hutcheson, Nilsen, Fadden, & Franklin, 2019), but much has been done to assist students in mapping the assets of team members through cognitive mind mapping (Curşeu, Chappin, & Jansen, 2018; Curşeu & Pluut, 2013). But Dahlin, Weingart, and Hinds (2005) discovered that while the diverse student teams had more information available, they did not use it well. The more formidable challenge lying beyond understanding the resources available is how to incorporate the known assets into a cohesive solution (Gardner, Gino, Staats, 2012).

A second factor is the inconsistency of results for team charters versus time. Team charters—statements of who will do what and how—created at the beginning of team functions have helped student teams reach their goals (Aaron, McDowell & Herdman, 2014; Byrd & Luthy, 2010), but deep-level influences tend to expose areas of conflict that inhibit effective coordination (Harrison et al., 2002; Srikanth et al., 2016), especially in short-term team scenarios (Cronin & Weingart, 2007; Huber & Lewis, 2010). For example, Van der Vegt, Bunderson, and Oosterhof (2006) found that students are more committed to teammates that they perceived to have more expertise than others. This impacted to what extent the students helped one another, which then created tension and a decreased capacity to meet goals (Paletz, Chan, & Schunn, 2017). Thus, simply perceiving cognitive differences significantly changed the intragroup dynamics of these teams as it related to coordination. While it seems team charters help to map out coordination among team members, research results that help to understand and account for the cognitive diversity are still lacking. Therefore, more must be done to not only understand the dynamics of student teams, but to improve their efforts to integrate, coordinate, and work well in group contexts of abundant deep-level diversity.

In conclusion, as student teams are organized by deep-level, cognitive differences their capacity to coordinate, manage conflict, and collaborate are negatively affected. Harrison, Price, Gavin, and Florey (2002) suggested that these negative effects intensified through the students' work together. The inability to implement a process where students can synthesize and integrate knowledge assets from diverse individuals in their own team has serious costs in the short and long term. Indeed, they suffer the loss of crucial opportunities for creativity and innovation (Perry-Smith & Shalley, 2003; Men, Fong, Luo, Zhong, & Huo, 2019; Morrison et al., 2019), practicing leadership and communication (Klein et al., 2011; Pöysä-Tarhonen, Elen, & Tarhonen, 2016), and other essential skills and traits of being good team members (Lorinkova & Bartol, 2020; Edmondson, 2019). Student teams need help in integrating diverse knowledge as such diversity in and among team members and team work is only becoming a natural part of the world in which we live.

1.3 Significance

Stiehm (2002) related that even in peace time, students in war colleges (and arguably in any other educational environments must still prepare to survive and thrive in a VUCA world—"volatile, uncertain, complex, and ambiguous" (p. 6). "A serious risk factor in any company facing volatility, uncertainty, complexity, and ambiguity," Edmondson (2019) wrote, is having information to share and not being able to do so (p. 19). "Today's problems simply demand that [teams]…work together to integrate their separate knowledge bases and skill sets to forge coherent, unified solutions" (Gardner, 2017, p. 1). But integrating knowledge is a serious challenge, especially by teams intentionally designed for diversity of thought (Pennington, 2016). Therefore, those teams that can integrate their vast knowledge into strong, unified solutions reap great rewards. Such benefits include increased team creativity (Perry-Smith & Shalley, 2003; Hoever, Van Knippenberg, van Rinkel, & Barkema, 2012), quality of team communication (Bradley, Baur, Banford, & Postlethwaite, 2013; Woolley, Chabris, Pentland, Hashimi, & Malone, 2010), collaborative problem solving (Mabley, Ventura-Medina, & Anderson, 2020), and overall team effectiveness (Mehta, A. & Metha, N., 2018).

However, students who are preparing for the workforce are not given proper education in how to conduct and lead effective knowledge integration in cognitively diverse teams. In fact, the odds of success are stacked up against them. Student teams are usually organized for a short amount of time (a typical 16-week semester or less), which is associated with legitimate issues in effective coordination (Fisher, Bell, Dierdorff, & Belohlav, 2012; see also Srikanth et al., 2016). Working in a team that is high in cognitive diversity has generally made knowledge integration more difficult for student teams (Dahlin et al., 2005; Harvey, 2013). Lastly, students may be given opportunities to map the assets of diverse team members (Curşeu, Chappin, & Jansen, 2018; Curşeu & Pluut, 2013), but such visualizations do not necessarily offer insights into how to begin to link and leverage assets towards an integrated solution (Gardner et al., 2012). Thus, more must be done to assist students in not only recognizing but how to work with the cognitive diversity inherent in their teams.

The world in which we live is increasingly volatile, uncertain, complex, and ambiguous and students need to be prepared to tackle the challenges of such an adaptive environment. One of the factors for why there is burgeoning complexity, is the growing exposure we have to the cognitive differences of a diverse, globalized society (Robertson and Schoonman, 2013; Roberson, 2019). In preparing students to recognize and effectively integrate the assets found in the cognitive diversity in group settings, we will help them begin their professional careers with a significant advantage which enable them to compete, innovate, and succeed (Curşeu, Chappin, & Jansen, 2018; Loes, Culver, & Trolian, 2018; Loes & Pascarella, 2017).

1.4 Purpose

The purpose of this study is to investigate two competing models for visualizing and understanding individual and team cognitive diversity which have shown potential to improve knowledge integration in student teams and the impact these models also have on team psychological safety and contribution to team activities.

In selecting which measures of cognitive diversity to use, those measures that also supplied strong theoretical frameworks for explaining interactions among team members were chosen over others. In past research, students simply knowing they are in a diverse team has not inspired effective integration of knowledge among team members (Pöysä-Tarhonen, Elen, & Tarhonen, 2016; Cronin & Weingart, 2007; Huber & Lewis, 2010; Heath & Staudemnmayer, 2000); a strong framework that could help explain interactions among members to students was hypothesized to be more effective (see Strijbos, Martens, Jochems, & Broers, 2004).

Additionally, knowledge integration in teams is moderated by psychological safety: a shared belief among team members that the team serves as a safe place for members to take interpersonal risks (Edmondson, 1999, 2004). In fact, teams organized based on variables of cognitive diversity failed to collaborate when psychological safety was not present (Reynolds and Lewis, 2018). Therefore, measuring psychological safety as part of this study is important to ensure that the necessary chemistry that enables knowledge integration to occur is in place.

Another factor in selecting which variables to use that would best fulfill the purpose of this study, was the nature of the theoretical framework upon which the model was founded upon. Simply using two different measurements for the same variable (i.e., personality) from divergent views in a single discipline (i.e., psychology) may not produce results that would influence praxis in a practical and relevant way. Whereas two different variables rooted in two opposing theoretical frameworks, may help advance our purpose further in understanding what models best help student teams integrate knowledge. Thus, the two variables of cognitive diversity to be investigated in this study, are strategic agility (based in evolutionary theory) and creative problem-solving preferences (rooted in theories in psychology).

The compilation of one's attachment focus, optimization-exploration orientation, and management of complexity is called, for the purposes of this study, *strategic agility*. Robertson and Schoonman (2013) have found that, from an evolutionary standpoint, human beings have two strategic attachment styles: attachment to people or to content. This continuum of attachment reveals how some of us experience the world around us with either a focus on relationships or a focus on craft, theory, or some subject matter. Another evolutionary development is the continuum of stability or optimization to exploration. It was an important instinct of our ancestors to rely on the proven method of living in a cave, but others pushed the boundaries on what was possible and helped propel the species forward with curiosity. Neither approach was or is inherently better than another, but two important polarities that help stabilize and transform mankind. Finally, there are varying levels of management of complexity: some focus on expertise while others care more about integration. Strategic agility thus provides a unique perspective into how a person (as an individual attribute) and a team (as a team construct) responds to change.

The other variable to be considered in this study is that of creative problem-solving preferences. Kirton (1976) recognized that people express themselves creatively in different ways, but it was Puccio (1999), standing on that theoretical foundation, that discovered that people have deep psychological preferences for various stages of the creative problem-solving process. Puccio and others (DeCusatis, 2008; Puccio & Acar, 2015; Puccio, Miller, & Acar, 2018) have found that some prefer the early stages of defining problems whereas others prefer coming up with ideas; or that others prefer to develop and refine solutions while still others prefer implementing solutions. Such creative problem-solving preferences do not denote ability, but they do describe a level of cognition that deeply affects team dynamics (DeCusatis, 2008; Puccio & Acar, 2015). In fact, Puccio and Cabra (2010) summarized:

> Leaders who employ strategies and knowledge associated with *individual creativity*, creativity processes, and creative environments stand a greater chance in bringing about organizational creativity that will ultimately lead to higher levels of both internal and external innovation (pg. 166; emphasis added).

Another additionally salient and advantageous reason for using the two variables of strategic agility and creative problem-solving preferences is that investigating them provides a complex look at variables of cognitive diversity that are often not studied together (Mello and Rentsch, 2015) thus giving a more holistic view of human cognition in a team context. Researchers in organizational settings (Matheiu et al., 2019; Matheiu et al., 2014 Srikanth et al., 2016; Humphrey & Aime, 2014) have called for more multilevel, multi-theoretical approaches to the study of teams. While this study is focused on student teams, the multi-theoretical foundations applied therein will help to answer this invitation for more robust research in team contexts. Thus, this study will be an effort to help student teams overcome barriers to successfully collaborating and sharing knowledge assets by using theory-based models of working with cognitive diversity while also advancing our understanding of how two distinct variables interact in student team settings.

1.5 Research Questions

The research questions that will be addressed in this project are as follows:

RQ1: Is strategic agility correlated with knowledge integration capability when controlling for psychological safety?

RQ2: Is creative problem-solving preference correlated with knowledge integration capability when controlling for psychological safety?

RQ3: Which framework (strategic agility or creative problem-solving preference) helps students score higher in knowledge integration capability when controlling for psychological safety?

RQ4: Is strategic agility correlated with team member contribution when controlling for psychological safety?

RQ5: Is creative problem-solving preference correlated with team member contribution when controlling for psychological safety?

RQ6: Which framework (strategic agility or creative problem-solving preference) helps students contribute equally across team members?

These questions will be used to guide the development of a research design that will enable the researcher to perform a rigorous and thorough correlational study for research questions 1, 2, 4, and 5, while a quasi-experimental posttest experimental approach will be used to help answer research questions 3 and 6.

1.6 Assumptions

The first assumption that will be made in the course of this study is that the many student respondents will provide not only truthful, but consistently accurate answers about themselves on the *FourSight* and *AEM-Cube* assessments. Statements of gender, major, course section, and so forth that the students will self-report in conjunction with the assessments will also be assumed by the researcher to be accurate and consistent. Equally held will be the assumption that students will respond truthfully about themselves and their teammates on the survey regarding psychological safety.

1.7 Delimitations

Students who do not complete the course (either through dropping or withdrawing from the class) will not be considered in the data analysis and final report. Also, measures or controls for conflict resolution, team effectiveness, and managerial effectiveness will not be considered.

The variable of psychological safety as it relates to diversity and team performance is sufficient for this study.

Lamm et al. (2012), Wen et al. (2016), and others (Campos et al., 2015; Hoch & Dulebohn, 2017; Mathieu et al., 2014; Layton, Loughry, Ohland, & Ricco, 2010) have experimented with the composition of teams by manipulating which individuals were on what team to understand the impact of cognitive diversity on innovation (or some other outcome). The purpose of this study, however, is not to intentionally create more or less diverse teams, but rather observe the correlations of several variables of team diversity that may influence how members work together. Thus, by allowing student participants to choose their own team members, the researcher is allowed to be objective in how the variables influence and impact each other, if at all.

1.8 Limitations

This research study will be completed in the early months of the year 2021 and the nature of the COVID-19 pandemic and its effects on this study, even as this is written, are not entirely known. Though the proposed study is not highly invasive on the student experience, the learning experience could be affected by the university restrictions and policies regarding the pandemic and therefore, so could the results of the study. For example, psychological safety survey responses from students may be influenced by whether or not one of their team members wore a mask as outlined by the university (confusing psychological safety with physical safety), even though there is no such mention of physical safety incorporated in the validated psychological safety survey. Ultimately, this study may be influenced by the COVID-19 pandemic in unexpected ways and thus could potentially limit the replicability of this research project.

This study is being conducted on a university campus with freshman undergraduates and not in a corporation or organization from industry. Thus, the generalizations to the broader population of the United States workforce will not be possible.

Additionally, there will be no qualitative methods used to further understand the correlation. The size of the sample, time limitations, and context of the study taking place in what may be unfavorable circumstances due to the COVID-19 pandemic, made observations of team behavior very difficult. Thus, the choice of using all quantitative measures—through assessment and survey—is ample to provide enough information to answer the research questions in as thorough a manner as possible.

1.9 Definitions

Surface level diversity. “Overt demographic characteristics” that are readily apparent to others, such as age and race (Bell, 2007, p. 596; Matheiu et al., 2019).

Deep level diversity. “Psychological characteristics such as personality factors, values, and attitudes” (Bell, 2007, pg. 596).

Functional diversity. “Refers to a team composed of individuals from different functional areas or backgrounds” (Matheiu et al., 2019, p. 26).

Cognitive diversity. [Operational definition; adapted from (Mello and Rentsch, 2015)] A team- or organizational-level variable that refers to several varied thinking, processing, and cognitive tasks that consists in a group or organization. Simply put, “differences in the cognitive processes that people employ to accomplish their tasks” (Kurtzberg, 2005, pp. 53-54).

Strategic agility. [Operational definition] Simply, evolutionary characteristics that determine how a person approaches change or complex tasks. It is a variable of human cognition that is comprised of one’s attachment style (relationship vs. content), orientation or preference for exploration or optimization, and their preference for integration or expertise. This variable, when quantified, can then be plotted on an S-curve or growth curve thus describing the type of contribution to the strategic purposes of a team or organization, thus it is named strategic agility.

Creative problem solving. Creative problem solving, as a general term can refer to “any activity during which an individual, team or organisation attempts to produce novel solutions to ill-defined problems” (Puccio, 1999, p. 171). However, Osborn’s (1953) specific model of applied creativity, named Creative Problem-Solving, provides “process steps and cognitive strategies that enable individuals, teams, and organizations to more effectively respond to open-ended challenges” (Puccio, Miller, & Acar, 2018, p. 576).

Psychological safety. “A shared belief held by members of a team that the team is safe for interpersonal risk taking” (Edmondson, 1999, p. 350).

CHAPTER 2. REVIEW OF THE LITERATURE

2.1 Methodology of the Review

2.1.1 Introduction

The problem addressed by this study is that student teams do not integrate the knowledge available to them very well in cognitively diverse teams. The purpose of this study then, is to provide student design teams with models or frameworks for visualizing and understanding the cognitive diversity available to them in their team and test the impact these frameworks have on various measures of team effectiveness: knowledge integration, psychological safety, and individual contribution.

A wide net across organizational and educational research was cast to conduct a literature review to supply apposite and supportive findings for the problem and purpose of this study. Thus, databases providing information specific to specialized organizational research were considered as well as those for education-based interventions. Search terms were carefully crafted to provide a continuum of focused-to-broad search results to ensure a thorough review of the literature. Figure 1 was created to clearly map the methodology of the review. While only three major search terms are displayed in the figure, some variations were used to maximally exhaust the database resources and are briefly described in later sections.

2.1.2 Research databases

ProQuest Dissertations & Theses (PQDT) Global. PQDT is the first database that was used as it is considered by the host university librarian as the most inclusive and comprehensive database to search for dissertations and theses available. One can gather dissertations and theses from the 18th century from all over the world, therefore, there was some confidence on the part of the researcher that one can gather authoritative articles from anywhere at any time in distant or recent history on the concepts related to this study.

Due to the vast depth of this database, preliminary limitations were used in the advanced search to help narrow and focus the search results. In this database, “source types” that were of interest were “dissertations & theses” and works from “scholarly journals.” Document types that were selected were “articles”, “book chapters”, “case studies”, “conference papers”, “dissertations/theses”, and “literature reviews”. These were selected as these are typically peer-reviewed or, in the case of dissertations and theses, undergo serious review by expert committees thus these document types exemplify peer-reviewed or accepted research. English was selected as the preferred language for all results. The generalizable population are student teams in the United States, thus only research conducted in the United States was of interest in this review. Finally, only research published in the last 5-10 years was considered.

PsycINFO via EBSCOhost. The framework of the proposed study is largely based in psychological theory. This database came by recommendation from the online librarian at the university the researcher is associated. The characteristics of this database share the same user-interface as EBSCOhost. Additional restrictions put in place for the search beyond the Boolean phraseology presented in Figure 1. Such restrictions included publications in the last ten years and a limitation to academic journals and dissertations, as these are peer-reviewed or have been under review by experienced committees.

ERIC. This study investigates the nature of student teams and thus a search database associated with educational research was needed. The ERIC database is sponsored by the US Department of Education and is the leading source for education-related research. This database was used to find any relevant literature in educational settings. Similar constraints as used in the PQDT database were used: such as research based in the United States that has been conducted within the last 5-10 years.

Academy of Management. The Academy of Management (AOM), and its affiliates journals, is considered by many in the field of management as one of the flagship journals for business and management research. The online search engine associated with the Academy’s publications is much less refined, but its search of a very focused area allows one to get the top peer-reviewed articles in the field in one place. Because this database is less robust in its search capabilities, it was only used once in an area where general search terms would yield more results.

Contacting lead researchers. For this literature review, several lead researchers in the fields of cognitive diversity and teams were contacted for recent works. Some researchers’ personal Google Scholar page(s) were particularly helpful in gathering recent literature reviews or investigations into relevant subjects. From these several articles, the reference sections were especially useful in furthering and also confirming current literature review searches—a method recommended by Gay, Mills, and Airasian (2012).

2.1.3 Literature search

Based on Figure 1, there were three main search phrases used (i.e. "Knowledge integration AND diversity…etc.") to conduct the literature review. These phrases ranged from focused (e.g. *Knowledge Integration AND Diversity AND Student Teams*) to broad (*Teams AND Deep level diversity)* helping to capture a wide range of literature potentially relevant to the study of interest. Generally, this approach yielded substantially useful results and the consistency of search terms provided a narrowing of redundant articles across databases. However, variations of these search terms were used occasionally—such as leaving out *diversity* in the first search term or switching *deep level diversity* for *cognitive diversity*—within the databases to assure a thorough investigation of relevant research was gathered. Admittedly, some of these variations yielded less results than the original search phrases whereas, as in the case of the PQDT database, thousands of items came in result of variations, but were only relevant because they included the phrase "student" or "team" and did not have any apposite findings or focus.

Some databases proved both more abundant and helpful than others. PsycINFO, for example, was only used on two specific search phrases because by the second search phrase, there were several redundant results. Whereas the AOM database—because of the lack of its robust search capabilities—proved to be most helpful in the broad search terms of *Teams AND Deep level diversity,* with some variations in whether deep level or cognitive diversity was used. Otherwise, thousands of results came back being only relevant because the words "team" or teams" were found somewhere in the suggested documents.

Contacting lead researchers provided several works specific to the variables of interest and a few instruments to measure the variables. Leading researchers in areas of cognitive diversity and teams provided a large number of focused pieces that aided in the literature review. However, many were repeated from the previous database search.

All search results were further analyzed by reading the abstract and contents to ensure maximum relevancy to the problem and purpose. For example, studies of students outside the United States were not considered relevant. Organizational studies of teams were included as these provided some methodological and theoretical foundations to the potential research design.

Duplicates were found in the search results across databases and search terms and were thus eliminated. Cumulatively then from the databases and research sources used in the preliminary search of the literature, 144 publications—ranging from dissertations/theses to journal articles and conference papers—were found and collected for the use of this review and study.

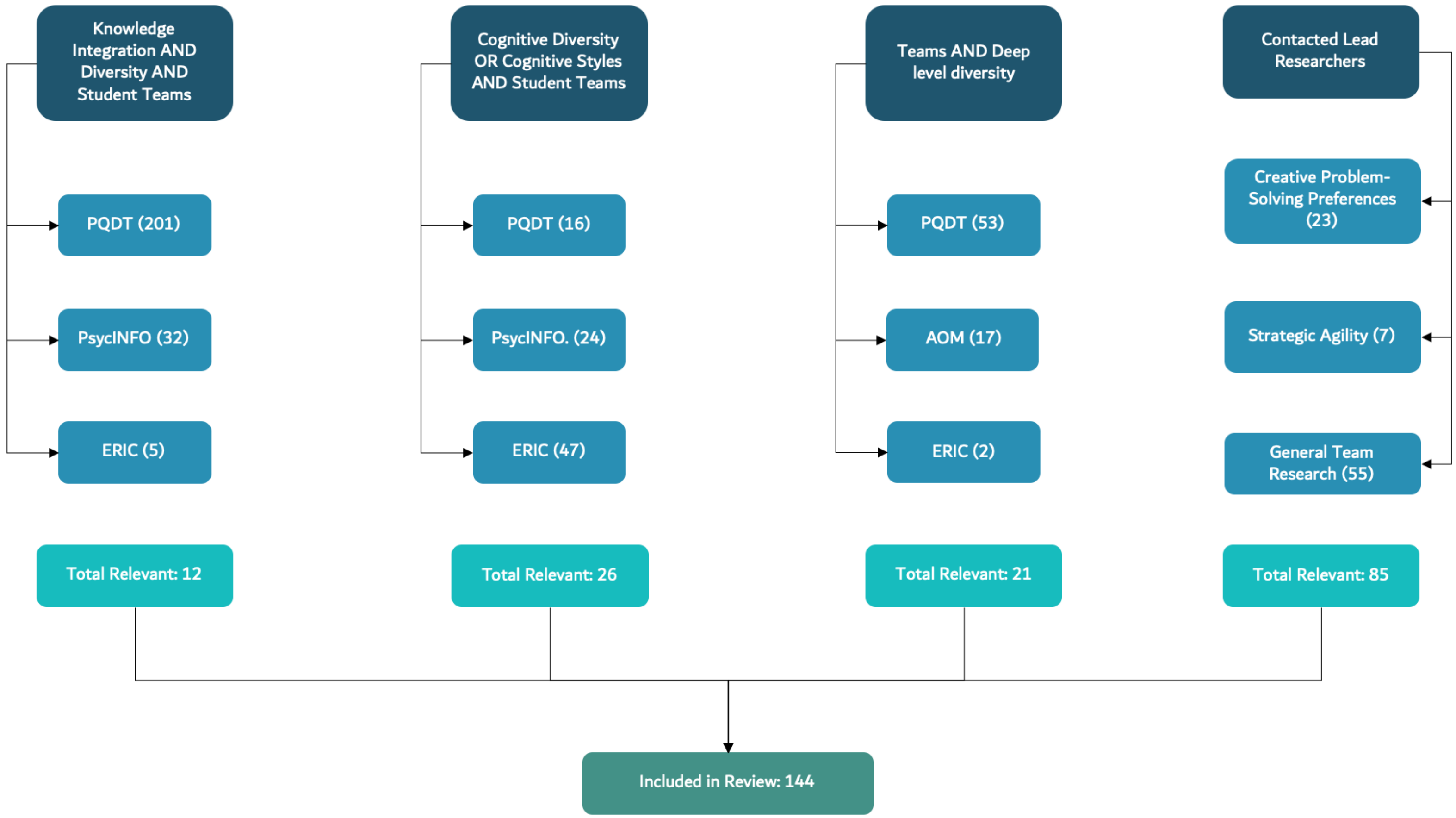

Figure 1. Search Strategy for Acquiring Literature for Review

Note. There were three major Boolean search phrases used, however slight adaptations to the search terms were used, but are not represented here. Databases display the total number of articles found using the associated search term. Total relevant articles per search term recorded.

2.2 Findings Pertaining to the Problem & Purpose

Whether in the physical or virtual classroom, students are regularly organized into teams (Riebe, Girardi, & Whitsed, 2016). The purposes for these teams vary. Some teams are for the benefits of learning from others (Loes & Pascarella, 2017), peer-feedback on assignments (Loignon et al., 2017), or to practice skills in a group setting (Fox et al., 2018). As teams make up the heart of innovation (Gilson, Lim, Litchfield, & Gilson, 2015; Menning, Ewald, Niolai, & Weinberg, 2020), students will continue to be placed in teams to prepare for a globalized economy that has accepted that innovation is the ultimate competitive advantage (Limi & Trimi, 2018; Chen, Li, Chen & Ou, 2016; Getz & Robinson, 2003). But, as Menning, Ewald, Niolai, and Weinberg (2020) have stated, "the equation is not simply more people = more diversity, more knowledge, and more work power" (p. 133). There are several barriers to student team success in the context of design and innovation (Mabley, Ventura-Medina, & Anderson, 2020).

Innovation is a by-product of intentional creativity (Runco, 2014), thus a team's ability to harness individual and collective creativity is crucial when tasked to innovate (Paulus & Nijstad, 2019). However, idea fixation (Jansson & Smith 1991; Linsey et al., 2010; Purcell & Gero, 1996), evaluation apprehension (Diehl & Stroebe, 1987; Zhou et al., 2019), social loafing (Karau & Wilhau, 2020; Latane, Williams, & Harkins, 1979), groupthink (Janis, 1972; Kim & Ha, 2019), issues of trust (O'Brien, 2018), among others (Paulus & Nijstad, 2019) have all been long-standing obstacles to harnessing the creative assets available in a team. Paletz, Chan, and Schunn (2017) even found that how student teams manage micro-conflicts can determine not only the level of uncertainty that a team experiences in a design challenge but also as to whether or not they are successful in achieving the desired end results. These challenges have been and can be ameliorated through formal interventions (Okhuysen & Eisenhardt, 2002; Brewer & Holmes, 2016), but there are more challenges when it comes to designing student teams—or any team of working adults, for that matter—for diversity.

Decades of research has shown that diverse teams outperform more homogenous others (Jackson & Ruderman, 1995; Bassett-Jones, 2005; Lamm et al., 2012). In theory, this is the result of cognitive or deep level diversity as these teams have an immediate advantage through an increase in available knowledge assets over less diverse groups (Menning et al., 2020; Roberson, 2019; Srikanth et al., 2016; Mathieu et al., 2014). The competitive advantage of innovative teams is real and how to develop student teams with diversity for both pedagogical benefits and the possibility of developing innovative solutions is also of keen interest (Matheiu et al., 2014; Mathieu et al., 2019). But there are contradictory findings across the diversity literature confounding efforts to reach consensus as to what type of diversity is most successful (and consistent) in achieving the desired results.

Tshetshema and Chan (2020) summarized well the contradictions inherent in the study of demographic or surface level diversity and teams: Age diversity is associated with communication breakdowns through generational-value differences but conversely, age diversity may also be linked to reduced conflict at the group-level (see also Lee, Lee, Seo, & Choi, 2015); cultural diversity can lead to more creativity, but conflict arises surrounding the dominant culture, perceived power distance, and one's identity based on culture; gender diversity has more positive effects but appears to be contingent on task importance (i.e. the more important, the more value in having women on a male-dominant team; see Neumeyer & Santos, 2020) and the frequency of interaction among team members (the more frequent the better) and where these factors are not present "gender-diverse teams should be avoided" (p. 963). Therefore, Shin, Kim, Lee, and Bian (2012) suggest that a deeper form of diversity may be more significantly related to creativity in teams as deep level diversity is more closely associated "with creativity processes rather than with social categorization processes" (p. 200), which demographic diversity tends to be (Mello & Rentsch, 2015; Horwitz & Horwitz, 2007).

Functional diversity has its own specific contradictory results as well. Functional diversity has shown at times to be successful when combined with other types of diversity (Hewlett et al., 2013), but in longitudinal studies has proven to produce poor performance on its own (Bell, Villado, Lukasik, Belau, & Briggs, 2011). This is assumed to be because of conflicting values among team members (Jehn et al., 1999) and, though often unmeasured (Srikanth et al., 2016), because of social categorization issues. Therefore, the diversity for which Shin et al. (2012) argued as being more closely aligned with creativity may be more associated with psychological traits than one's functional or demographic attributes. While even this level of diversity is widely studied with some inconsistencies (Mello & Rentsch, 2015), there is overwhelming evidence that the cognitive dynamics of groups and teams has a significant impact on team and organizational functioning (Barsh & Lavoie, 2014; Boaz & Fox, 2014; Blackburn, Ryerson, Weiss, Wilson, & Wood, 2011; Langer, 2014; Heifetz, Grashow, & Linsky, 2009; Keller & Price, 2011; Keller, Price, Hamel & McKinsey & Company, 2010; The Arbinger Institute, 2016; Kotter, 1995).

Thus, there has been a double-edged sword view of team diversity (Srikanth et al., 2016; Mathieu et al., 2019). Hawlina, Gillespie, and Zittoun (2019) reiterated and summarized well Bassett-Jones's (2005) observation that "companies in the 21st century face the paradox of diversity management, creativity, and innovation – either they embrace diversity and risk workplace conflict, or avoid diversity and risk lesser creativity and consequent decreased competitiveness" (p. 134). But the axiomatic concept of diversity opening the doors to novelty and better solutions has the researchers pursuing ways in which we can overcome the balancing act mindset and unify the cognitive advantages and cohesiveness of strong teams (Hawlina et al., 2019).

For students, one such level of diversity showing promise in accomplishing that goal is in one's creative problem-solving preference. Lamm et al. (2012), in a study of undergraduate students in an agricultural program, discovered that there were benefits and drawbacks to organizing teams by problem solving style in homogenous or heterogenous groups. A specific drawback is that students organized into homogenous groups that have a stronger tendency towards innovating will perform better than a homogenous group that have more stability-focused preferences. On the other hand, heterogenous groups of varying styles were better able to apply effective problem-solving strategies. However, while similar results have been found in industry settings as well (Campos et al., 2015; Miron-Spektor, Erez, & Naveh, 2011; Michael, 2018) other competing models have shown promising findings.

A different variable associated with how one approaches change—referred to as *strategic agility* for the purposes of this study—has been associated with more efficient team problem-solving. Reynolds and Lewis (2017) conducted a study of several work and educational teams tasked with working to solve a complicated problem-solving activity in a specific amount of time. When the teams were formed through physical attributes of diversity, or bio-demographic diversity, the speed by which the teams completed the activity was not affected. However, when the teams were organized based on a balance of varying traits of strategic agility, the speed and accuracy which the teams completed the challenge significantly improved. While speed may not be associated with quality innovation, a limited time to complete a task is relevant to work in student teams and has been shown to be a major factor (Cronin &Weingart, 2007; Huber & Lewis, 2010). Thus, there may be some advantage to teams diverse in strategic agility that enable them to streamline problem-solving processes and producing appropriate results.

For example, teams that have an exploratory focus have bene shown to intrinsically engage in knowledge sharing behaviors (Gong, Kim, Lee, & Zhu, 2013; Chadwick & Raver, 2015; Metha & Mehta, 2018). Strategic agility, with its basis in ethological, cybernetic, and complexity theories can explain, to some extent, why this may be so. As one feels confident in the stability of their relationship, they are willing to explore and learn from the associated environment. However, the caveat is the security of the relationship. If this is not present, exploratory learning is not possible.

In a follow up study, Reynolds and Lewis (2018) discovered that teams composed of diverse members based on a self-reported measure of strategic agility were only successful if psychological safety was also present. Psychological safety—the shared belief among team members that no one will be ridiculed or mistreated for taking interpersonal risks (Edmondson, 1999, 2004, 2019)—has been shown to be a powerful moderating variable in team effectiveness (Edmondson & Lei, 2014). In fact, in a study conducted at Google, Rozovsky (2015) uncovered psychological safety as being "far and away the most important of the five dynamics we found—[as] it's the underpinning of the other four [being dependability, structure and clarity, meaning of work, and impact of work]" (par. 11) (see also Duhigg, 2016). However, psychological safety is often misunderstood as helping everyone feel comfortable. Rather, psychological safety is a group construct that is metaphorically, like whether a light is on in a room: if it is off, working as a team in the dark is extremely difficult and unsuccessful whereas with the light on, the team can better tackle the challenges at hand. Psychological safety in teams allows for members to speak up when there are problems, critique, fail, debate, share interest in one another, and experiment without degradation (Edmondson, 1999, 2004). Such interpersonal risks can still be uncomfortable, but they must be taken to achieve learning and innovation (Edmondson, 2019; Bergmann & Schaeppi, 2016; Duhigg, 2016; Edmondson, Higgins, Singer, & Weiner, 2016; Garvin, Edmondson, & Gino, 2008). But, as in the context of the earlier metaphor, just because the lights are on, does not remove other obstacles to effective teamwork.

In fact, the greatest challenge facing cognitively diverse student teams still remains: acknowledging and integrating the knowledge assets available to them in their teams (Srikanth et al., 2016). Knowledge integration takes place when team members "combine their unique knowledge and skills to address a shared […] problem" (Pennington, 2016, p. 299) and is an essential component to team success (Metha & Metha, 2018) but is especially difficult in interdisciplinary teams (Pennington, Simpson, McConnell, Fair, & Baker, 2013; Bodla, Tang, Jiang, & Tian, 2018). The reasons for knowledge integration failure in diverse student teams lie more in cognitive and process-oriented differences: it is difficult for cognitive differences to be understood and utilized in a short period of time (Huber & Lewis, 2010; Cronin & Weingert, 2007 Heath & Staudenmayer, 2000), the lack of leadership skills (Klein et al., 2011; Oosthuizen, De Lange, Wilmshurst, & Beatson, 2020), and other coordination problems (i.e. schedule, differing mental models, etc.) (Fisher et al., 2012; Newell et al., 2005).

Much has been done to address the problem of failed knowledge integration in recent years by providing students the opportunity to use cognitive mind mapping to represent knowledge and skills assets possessed by individual team members (Curşeu & Pluut, 2013; Stoddard & Pfeifer, 2018; Coman et al., 2019). However, identifying and assembling available resources is one step, integrating them is another. Gardner, Gino, and Staats (2012) argued that "integrating resources is inherently a challenge in coordination, which is not a static exercise" and "successful performance depends on continuous integration as circumstances change—a *knowledge integration capability*" (p. 1001; italics in original). Thus, knowledge integration is more about the processes and strategies the team uses to draw on the available resources over time (Marks, Mathieu, & Zaccaro, 2001) rather than a stagnant well of assets that recombine into a novel product or outcome.

Some process-oriented research has shown benefits related to knowledge sharing (Lee et al., 2015) and knowledge integration. For example, when team members focus on perspective-taking—considering the perspectives of other members when in communication about ideas or tasks (Hoever et al., 2012)—or practice formal coordination—the extent to which team members adhere to a set of procedures to guide them in their work together (Dey & Ganesh, 2020; Shuffler et al., 2018)—they are generally more creative (Hawlina et al., 2019), experience greater cohesion (Dey & Ganesh, 2020), and achieve many of their goals (Shuffler et al., 2018; Aaron, McDowell, & Herdman, 2014; Byrd & Luthy, 2010; Sverdup & Schei, 2015; Mathieu & Rapp, 2009). But there is a serious gap in the research as it relates to the process of knowledge integration in student teams.

It is true that student teams improve with team charters (Aaron et al., 2014; Byrd & Luthy, 2010; Mathieu & Rapp, 2009; Sverdrup & Schei, 2015) or visualizations of available assets (Stoddard & Pfeifer, 2018; Curşeu & Pluut, 2013), but team dynamics derail when deep-level, cognitive differences are exposed more over time (Harrison et al., 2002; Srikanth et al., 2016). It is also true that teams with varying differences in creative problem-solving preferences or strategic agility better apply problem-solving strategies, but little is known on how these teams fare in their integration of knowledge and how such cognitive differences impact student team interactions over a period of time. Thus, the influence of formal coordination practices (such as team charters) in the context of creative problem-solving preferences and strategic agility on knowledge integration and team dynamics is under-researched and is the purpose of this study.

2.2.1 Summary

Students will continue to be placed in groups or teams for pedagogical purposes (Curşeu & Pluut, 2013; Curşeu et al., 2017; Loes & Pascarella, 2017; Loes et al., 2018). These teams typically last a short period of time and teams with cognitive diversity in such temporal constraints struggle to integrate the knowledge assets available to them (Fisher et al., 2012; Harvey, 2013; Dahlin et al., 2005; Newell et al., 2005) even if they are motivated to do so (Huber & Lewis, 2010; Cronin & Weingert, 2007; Heath & Staudenmayer, 2000). And while teaching leadership skills can help teams when differences are present (Klein et al., 2011), students often lack the experience to lead in contexts of diversity (Oosthuizen et al., 2020; Scott-Young, Georgy, & Grisinger, 2019; Han, Lee, Beyerlein, & Kolb, 2018) Therefore, frameworks are needed to help students not only make sense of the diversity around them but to harness the knowledge assets available to them that will lead to greater creativity and effectiveness.

Strategic agility and creative problem-solving preferences are two separate variables of cognitive diversity that provide strong theoretical and practical frameworks for how to interpret and engage with the diversity available in the team. Diversity requires rotating or shared leadership, which has been shown to dramatically improve team performance and team creativity (Lee et al., 2015; Davis & Eisenhardt, 2011; Lorinkova & Bartol, 2020). Strategic agility and creative problem-solving preferences have frameworks embedded in problem-solving or in the life cycle of a project thus providing direct scaffolding for users of the framework to apply methods of shared leadership to design tasks (Robertson, 1999; Roberston & Schoonman, 2013; Puccio, 1999; Campos et al., 2015). However, how effective these frameworks are in a classroom environment with the purpose of achieving better knowledge integration is perpetuating problem yet unsolved. Therefore, this present study could do much to elucidate which models help student design teams improve their knowledge integration.

2.3 Findings Pertaining to the Research Methodology

Some of the rationale for this study was synthesized from studies in organizational settings. While university undergraduates may express some cognitive differences than working adults (though some evidence suggests that there may not be that many; see Parrish, 2020), there is a real need to continue to investigate how organizational theories and models of effective teamwork influence the workings of student teams (Curşeu & Pluut, 2013). Undergraduate students are, in many ways, studying to prepare to enter the workforce, and their team experiences in classroom settings can be viewed as a sort of training ground for future teamwork dynamics later on in their careers. For example, recent research has shown that the creative process used by STEM students is very similar for professionals among several industries, thus some findings were relevant in both education and industry environments (van Broekhoven, Cropley, & Seegers, 2020). Therefore, applying methods rooted in organizational theories in educational settings in the context of creativity and innovation is both proven and valid for offering fairly reliable insights into overall team dynamics (Karlsson & Nowell, 2020; Curşeu et al., 2017; Srikanth et al., 2016; Bravo, Catalán, & Pina, 2019; Lamm et al., 2012; Oakley, Felder, Brent, & Elhajj, 2004).

2.3.1 Cognitive diversity variables of interest

Some studies have relied on what is termed *perceived* cognitive diversity rather than *actual* cognitive diversity. For example, Shin, Kim, Lee, and Bian (2012) and Men, Fong, Luo, Zhong, and Huo (2019), had participants rate others as to how much they believed their cohorts differed from themselves (perceived cognitive diversity) rather than employing measures of cognitive diversity on each individual and aggregating that to the whole team. This method is problematic in studying adolescents or young adults in educational settings as young individuals' "social cognitive understanding of their social world is often inaccurate and biased" (Lee et al., 2017, p. 181). Therefore, measures of actual cognitive diversity will provide a more accurate and reliable view of the diversity of team members than their self-reported perceptions of others.

Creative problem-solving preferences. There are several assessments that seek to measure creativity in individuals, however it was Kirton (1976) who wanted to evaluate cognitive styles (preferences) in the context of creativity. This is important has cognitive styles have been "shown to be good predictors of creativity over and above personal attributes" (Lomberg, Kollman, &

Stöckmann, 2017, p. 49; see also Harrison et al., 2002). Kirton's (1976) inventory is a seminal instrument in understanding the single dimension of those who are innovators (boundary-pushing) and adaptors (conformists) in the context of creative theory. And while the instrument is widely used (Lomberg et al., 2017; Miron-Spektor et al., 2011; Michael, 2018), has many flaws.

Kirton's (1976, 2003) premise was that "cognitive styles are not related to creative outcomes" (Lomberg et al., 2017, p. 49). Meaning, that cognitive preferences for how one approaches creative problem-solving is different from one's capacity to act in a particular way (Lomberg et al., 2017; Kirton, 2003). In Lomberg, Kollman, and Stöckmann's (2017) study of recent alum from a business school, they found that Kirton's initial premise was false. Instead, Lomberg et al. found that people have multiple cognitive styles that they rely upon though, "often…tend to have one preferred cognitive style that they will use" (p. 56). Thus, the complexity of cognitive styles is not well represented in Kirton's instrument.

Secondly, Kirton's instrument's results can become binary in the eyes of those who implement it as a researcher and as a participant (Miron-Spektor et al., 2011) where some are perceived as being creative (rated as an innovator) or not (rated as an adaptor). Such a view is inaccurate to human functioning (Runco, 2014) and the nature of the assessment (Puccio, 1999), but is easily misreported due to the one-dimensionality of the instrument.

Lastly, Kirton's inventory does not produce results that are easily translated into Osborn's (1953) Creative Problem-Solving model. This is significant for educational-based research as training programs centered on Osborn's creative problem-solving model have been shown through meta-analytic review to be one of the most effective in building creativity skills (Scott, Leritz, & Mumford, 2004). Osborn's model is for applied creativity, complete with "process steps and cognitive strategies that enable individuals, teams, and organizations to more effectively respond to open-ended challenges" (Puccio, Miller, & Acar, 2018, p. 576). Therefore, creating an assessment for problem-solving preferences in the context of a creative problem-solving model was sorely needed.

Therefore, Basadur's (Basadur, Graen, & Wakabayashi, 1990) assessment, the *Creative Problem-Solving Profile* (CPSP), was intended to measure cognitive preferences in the context of Osborn's creative problem-solving model. In addition to this new focus on the creative problem-solving model, Basadur posited that two information processing dimensions should be considered as being part of the process of creative problem-solving: (1) a continuum of concrete to abstract thinking and (2) a continuum of knowledge for ideation to knowledge for evaluation (Basadur et al., 1990; Puccio, 1999; Ray & Romano, 2013). The assessment produced four quadrants representing four distinct cognitive styles or preferences for how one approaches problem solving: Quadrant 1 = Generator; Quadrant 2 = Conceptualizer; Quadrant 3 = Optimizer; Quadrant 4 = Implementor (see Figure 2).

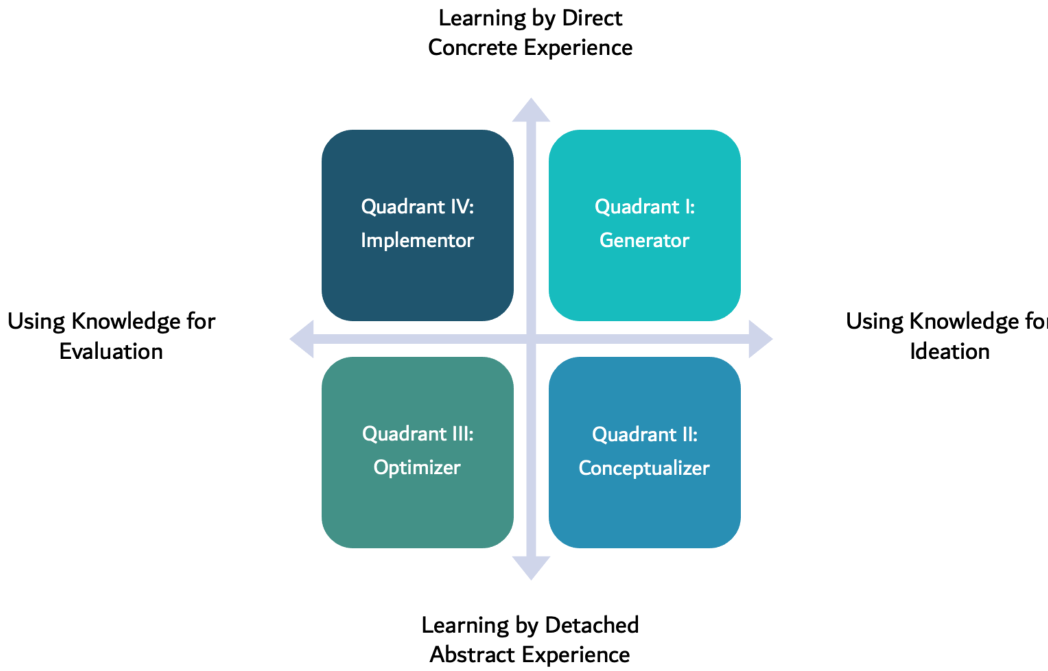

Figure 2. Basadur's Dimensions Comprising Creative Problem-Solving Activity
Note. Adapted from Basadur, Graen, and Wakabaysashi (1990, p. 114).

However, Puccio (1999) developed a different instrument—*FourSight*—with the same conceptual foundation as Basadur's (and, interestingly, both include four main styles), but with two distinctions. The first is that while Basadur focuses on the information processing dimensions "as the basis to his four preferences" (Puccio, Murdock, & Mance, 2005, p. 67), Puccio "focuses on the unique mental activities directly associated with each of the…[creative problem-solving] steps" (Puccio et al., 2005, p. 68). Secondly, Basadur's instrument requires assessors to rank order words, *FourSight* has assessors rate to what extent a statement of the creative process is descriptive of themselves (Puccio, 1999). The first distinction is noteworthy as *FourSight* does not "assume the existence of underlying information processing preferences" (Puccio, 1999, p. 173). Instead, *FourSight* narrowly focuses on the cognitive style, the psychological preference, for how one approaches creative problem-solving. Therefore, it is more inclusive and more varied in view of creative expression than Kirton's (1976) assessment while maintaining a direct link to the specific mental activities of the creative problem-solving model. *FourSight* then, is both a robust instrument and a theoretical framework for conceptualizing the creative problem-solving model within four major styles.

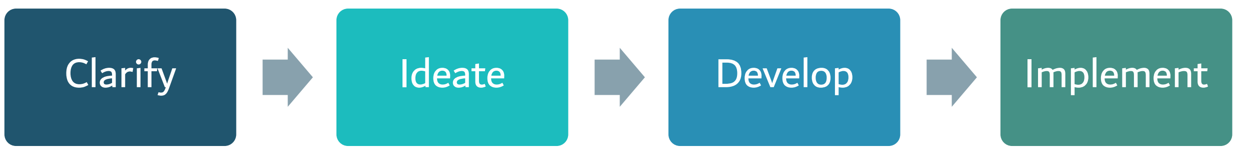

Figure 3. FourSight Problem Solving Model Based on Osborn (1953)

Note. Beginning from left to right, this model represents a basic approach to creative problem-solving as Puccio et al. (2018) describe it. Clarifying represents the stage where one seeks to understand the problem at hand. Ideation is where ideas for potential solutions are made. Development of the selected solution is then undertaken followed by Implementation of the solution.

The four major styles include *Clarifier, Ideator, Developer*, and *Implementor*. Those with a high clarifying preference prefer to work on the front-end of the problem by identifying root causes, searching for underlying or background information, collecting data, and perspective taking (Puccio et al., 2018, 576). Ideators, indicative of the term, generate ideas, are visionary and prefer to see the big picture (Puccio et al., 2018, p. 576). Developers lean towards refining and improving ideas or solutions already in existence and they do this "by evaluating different possibilities and comparing advantages and disadvantages of potential solutions" (Puccio et al., 2018, p. 577) and have a tendency towards perfection. Those with a high implementing preference are inclined towards action as they prefer to move to *the next thing* as quickly as possible (Puccio et al., 2018, p. 577). Each of these cognitive approaches to problem-solving can be linked together to showcase the entire problem-solving process, from clarifying all through to implementation.

DeCusatis (2008) compared the structures of teams of different generational backgrounds based on varying measures of personality or cognitive style. The *FourSight* model was found to be the best linked to frameworks for innovation, particularly, in theory, to those of a younger generation (Gen Y). Additionally, when the instrument was administered to teams at IBM, the assessment provided ample "self-awareness of a team's relative strengths and weaknesses" as to "increase the prospects for long-term success" (p. 164). But how this framework impacted knowledge integration, overall collaboration, and within the short-term was not reported and has not been studied. Thus, while the *FourSight* model and its associated assessment provide a focused deep dive into the creative problem-solving preferences for individuals, further research into the model's implications for knowledge integration is needed.

Strategic agility. Change is a prerequisite for survival (Robertson, 2005). From the moment an infant is born, there is rapid, radical change and development. This is turbulent and swift period of development is key to the infant's survival. This law of growth is true not only nearly all living things, but in the systems and organizations they create (Robertson, 2005). Thus, development or change is required for the survival of companies, governments, communities, and every other man-made institution (Robertson, 1999, 2005; Christensen, 1997; Robertson, 2014). Strategic agility, as a concept, provides an alternative view to visualize and understand how individuals can be organized into diverse team settings that can successfully explore and respond to change.

The unique theoretical foundation behind strategic agility provides an arguably deeper mapping of the cognitive processes of an individual than a cognitive styles approach, which often does not necessarily account for deeper information processing (Puccio, 1999). Even as strategic agility correlates well with personality (Roberston, 1999; Roberston & Schoonman, 2013), it serves a specific purpose in helping individuals and teams understand their orientations, preferences, and competencies around change. Therefore, there are three major theoretical underpinnings to strategic agility that arise from separate disciplines. The first is attachment from ethology, stability vs. exploration from cybernetics, and complexity management from complexity theory (Robertson, 1999, 2005).

Attachment. The basis for the attachment component of the strategic agility construct is derived from ethology. While ethology is a discipline mostly focused on the study of animals, translations into human contexts have been made in efforts to explain the "deeper" functions and reasons for human behavior (Bowlby, 1969, 1973, 1980; Lorenz, 1981; Lee & Hood, 2020). Attachment, then, describes the emotional tie or bond that a child makes with its parent or caregiver (Bowlby, 1969; Richins & Chaplin, 2020). However, there is also evidence of people who have stronger attachments to matter—technology, theories or concepts, ideologies, etc.—than to people (Lee & Hood, 2020; Altuwairiqi, Arden-Close, Bloat, Renshaw-Vuillier, & Ali, 2019). Thus, strategic agility takes into account the dimension of human-to-matter attachment. The attachment component is key in understanding the diversity of a team because the level of security one feels in their attachment (to people or matter) deeply influences to what extent they are willing to explore (Robertson, 2005).

Stability vs. exploration. The second component to strategic agility emerges from the first, as previously stated, but is derived from a cybernetical perspective on behavior. However, while attachment is an information and perceiving feed*back* system, exploration is an information and perceiving feed*forward* system (Robertson, 2005; Archer & Birke, 1983; Pickering 2010). To create stability, one looks for what has already been done, what is familiar, to regain that sense of security while someone focusing on exploration is a search for novelty or change (Archer & Birke, 1983). Thus, the concept of strategic agility accounts of a dimension of stability-to-exploration in terms of which system—feedback or feedforward—for which they rely in engaging with change.

Complexity management. Holland (2014) described complex adaptive systems as ever-changing systems of agents that "learn or adapt in response to interactions with other agents" (p. 8). The environment around an agent is in a state of accelerated, unpredictable change. Thus, in this light of complexity theory, Robertson (2005) stated:

> The degree to which one is able to assimilate one's experiences will influence the degree to which one generates the internal variety required to cope with the complexity of one's environment (p. 4).

The final component to strategic agility is one's management of complexity. Does one focus on integration (assimilating the parts) or more on specialization (making the local agent or environment better)? Such a focus impacts how one responds to change (Robertson & Schoonman, 2013).

These three components then comprise strategic agility which is not a theory, but a model (Robertson, 2005). Roberston (1999, 2005; Roberston & Schoonman, 2013) developed the *AEM-Cube* assessment to visualize this model of human behavior in a cube-dimension with the y-axis representing the dimension of attachment; the x-axis representing the dimension of exploration; and the vertical axis describing the level of one's management of complexity (Figure 4). This visualization combined with its explanation of human behavior offers a deeper explanation for human behavior in the context of change derived from multiple theoretical backgrounds. Therefore, using the *AEM-Cube* in this study would offer a competitive model to that of Creative Problem-Solving preferences in helping student teams understand the cognitive differences they possess and how to harness those differences towards effective knowledge integration.

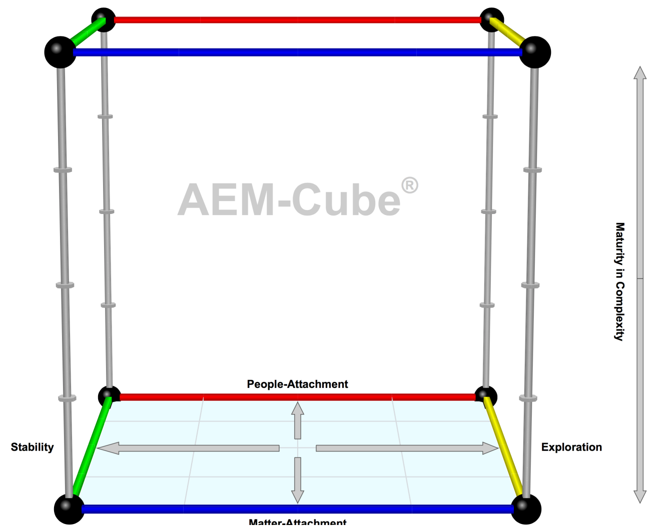

Figure 4. AEM-Cube Model for Strategic Agility

Note. This is a representation of the 3D model used to interpret scores on the AEM-Cube, the instrument intended to measure strategic agility. Management of complexity was originally described as maturity in complexity by the creators, but has since been changed. Used by permission by Human Insight, Ltd.

2.3.2 Study designs

In studying knowledge integration in student teams, research designs have followed a more traditional experimental design: students assessed for cognitive differences, organize student teams for heterogenous and/or homogeneous groups, teams complete a project together, and finally, the analysis of knowledge integration (Klein et al., 2011; Oosthuizen, De Lange et al., 2020; Curşeu & Pluut, 2013; Fisher et al., 2012; Coman et al., 2019; Harrison et al., 2002; Dahlin et al., 2005). Student teams are usually organized around functional or informational diversity such as academic major (Srikanth et al., 2016). To continue to do so in the proposed study, while also assessing creative problem-solving preferences and strategic agility, would provide a certain reliability through continuity in analysis. However, how knowledge integration is assessed has been different across studies.

Wen et al. (2016) had student teams created proposals for energy distribution across a city wherein the researchers later tallied the novel contributions incorporated into the final product. This type of analysis (performed by others; see also Dahlin et al., 2005) requires many evaluators, which is difficult for scalability and introduces the fallibility of interrater reliability. However, it may be a misdirection to focus on the tangible outcome of a team to determine effective integration of knowledge assets among diverse members. As Gardner et al. (2012) as well as Marks, Mathieu, and Zaccaro (2001) have stated, effective knowledge integration lies in "the processes team members use to interact with each other to accomplish the work" (Marks et al., 2001, p. 356; see also Mehta & Mehta, 2018). Therefore, analysis of knowledge integration capabilities in student teams should be of the process, not of the outcome.

Gardner et al. (2012) when studying knowledge integration in an accounting firm, used a self-reported measure of *Knowledge Integration Capability* that focused on the process the team used to effectively draw on the diverse cognitive resources available in the team. The survey, derived from Leathers' (1972) research on the relationship of quality communication and quality of team outcomes, encourages team members to reflect on the communication processes they used while working together and whether these processes enabled team members to integrate assets or not. Use of this measure and its adaptations has been successfully used in various settings (Leathers, 1972; Hoegl & Gemuenden, 2001; Gardner et al., 2012). Thus, measuring knowledge integration as a process rather than as a tangible outcome better aligns with the concept (Pennington, 2016).

Knowledge integration then as a process, requires certain facilitating variables. First, is psychological safety (Edmondson, 2019; Edmondson & Lei, 2014). Psychological safety has been used in educational settings and has shown to help students speak up, share information, and engage more fully in the learning process (Bergmann & Schaeppi, 2016; Edmondson et al., 2016). Important to the study of diversity in teams is the observation from Reynolds and Lewis's (2018) study with strategic agility that without psychological safety, cognitively diverse teams were ineffective. Therefore, the measurement of this construct is vital to understanding team success, but the construct requires some time for the team to work together to be reliably self-reported (Edmondson & Lei, 2014), thus measuring psychological safety during and at the end of a team effort or project enables the researcher to gain insights into the interpersonal dynamics of group processes.

However, measuring what happens at the beginning of team functions is also critical (Marques-Quinteiro, Ramos-Villagrasa, Navarro, Passos, & Curral, 2011). Thus, a second facilitating variable for knowledge integration would be creating a team charter at the outset of the project Several studies in researching the effectiveness of student teams have the participants create team charters—documents establishing ground rules and expectations (Aaron, McDowell & Herdman, 2014; Byrd & Luthy, 2010; Mathieu & Rapp, 2009; Sverdrup & Schei, 2015). While team charters are not a panacea for team conflict or procedural gaps, Shuffler et al. (2018) argued that teams that used team charters were more satisfied and demonstrated better team performance. For example, Aaron, McDowell, and Herdman (2014) measured team satisfaction and other group processes (communication, cohesion, and mutual support) at the beginning of the semester, oversaw the design of team charters at the beginning of the creation of business plans for two experimental groups (control group received no team charter), and then re-administered the group process measures. Two experimental groups differed in that one received instructor follow-up after the creation of the team charter while the other did not. However, no statistical difference was found among the two experimental groups; follow up did not impact the results of those who received a charter in the first place whereas those who received no team charter reported significantly less satisfaction in their team. Therefore, incorporating team charters is an effective way to ensure students meet their goals.

A method by which to measure team member contribution, is through the Comprehensive Assessment of Team Member Effectiveness (CATME) (Loughry, Ohland, & Moore, 2007). The CATME assessment measures student effectiveness across five major categories: contributing to team's work, interacting with teammates; keeping the team on track; expecting quality; and having relevant knowledge, skills, and abilities (Loughry et al., 2007). Using a peer-evaluation method, students rate themselves and their team members over the aforementioned categories and has shown high reliability and validity (Loughry et al., 2007; Loughry, Ohland, & Woehr, 2014). The criterion for which CATME assesses (Ohland et al., 2012) is similar to the team charter criterion as described by Aaron et al. (2014). Thus, utilizing the CATME assessment as a means to measure team member contribution in tandem with the use of a team charter in a learning environment is not incongruent with the assessment's purpose (Loughry et al., 2007; Ohland et al., 2012; Loughry et al., 2014).

However, team charters and psychological safety are only facilitators for knowledge integration, particularly those focusing on functional diversity (Van der Vegt, 2006; Paletz et al., 2017; Srikanth et al., 2016). Although, student team processes have a greater likelihood of demise as deeper-level differences become more evident (Harrison et al., 2002; Srikanth et al., 2016). Such a notion indicates several possibilities, two of which pertain to the present study: (1) that these cognitive differences were either hidden and therefore unknown to fellow student members or (2) were not carefully addressed in the beginning of their work together. Consequently, providing students with an opportunity to not only visualize but to address cognitive differences at the outset may be a significant differentiation in research method and analysis.

2.3.3 Summary

The methodologies employed to understand cognitive diversity in teams has been varied and rigorous, however a specific intervention into the knowledge integration capability of student design teams in cognitively diverse teams with the added intent of testing diversity visualization models is somewhat unique. The framework of *FourSight,* which describes creative problem-solving preferences, allows team members to understand the preferences (high, low, or neutral) of themselves in others in how they use their creativity to solve problems. The strategic agility model in the *AEM-Cube*, allows team members to visualize and understand why a team member reacts to change in the way that they do and potentially what area of the change process they may be best suited to focus on. Each offers a chance for team members to acknowledge and capitalize on the cognitive differences and knowledge assets available. However, a comparative analysis as to which model achieves better knowledge integration has not been undertaken. Therefore, beyond filling an ignorable gap between traits, a study to investigate the impact of these models on student design teams could be a significant step forward in aiding students engage with the cognitive diversity of their peers—something they will experience in a career and daily life beyond the classroom.

CHAPTER 3. METHODOLOGY

3.1 Introduction

When in cognitively diverse teams, students do not effectively integrate the knowledge available to them. Additionally, Srikanth et al. (2016) have indicated that students in such situations tend to get worse at collaboration as the cognitive differences emerge and are exposed over time. The costs of this lack of collaboration and assimilation of knowledge assets are significant, such as diminished creativity (Perry-Smith & Shalley, 2003). And where effective knowledge integration is lacking, so might also the moderating variable of psychological safety, which provides the basis for candid sharing of ideas and failures that could lead to increased learning and innovation (Edmondson, 2019). Therefore, the purpose of this study is to investigate among two competing models for visualizing and understanding cognitive diversity which improves knowledge integration in student teams tasked with innovation and the influence such models have on team psychological safety and individual contribution to team activities.

3.2 Research Approach

3.2.1 Review of research questions

RQ1: Is strategic agility correlated with knowledge integration capability when controlling for psychological safety?

RQ2: Is Creative Problem-Solving preference correlated with knowledge integration capability when controlling for psychological safety?

RQ3: Which framework (strategic agility or creative problem-solving preference) helps students score higher in knowledge integration capability when controlling for psychological safety?

RQ4: Is strategic agility correlated with team member contribution when controlling for psychological safety?

RQ5: Is creative problem-solving preference correlated with team member contribution when controlling for psychological safety?

RQ6: Which framework (strategic agility or creative problem-solving preference) helps students contribute equally across team members?

3.2.2 Approach for analysis

As reviewed in the previous section, RQ1, RQ2, RQ4, and RQ5 refer to the correlation of variables of cognitive diversity with certain group processes, such as knowledge integration and team member contribution while controlling for psychological safety. Thus, a correlational study would be undertaken to answer these questions.

RQ3 and RQ6, however, when considered together indicate an analysis of differences. For the purpose of this study, it is important to know whether strategic agility and creative problem-solving preferences in student teams correlate with knowledge integration and team contribution, but it is of equal importance to elucidate which framework for cognitive diversity yields greater knowledge integration and team contribution. This warrants a certain experimental design.

Previous researchers investigating the knowledge integration capability of student teams (e.g., Mehta & Mehta, 2018; Harrison et al., 2002) and in organizations (e.g., Gardner et al., 2012) have assessed the cognitive differences of team members, commissioned a collaborative task, and then surveyed knowledge integration and other group processes. A similar posttest methodology will be employed in the proposed study, however with some differences (see Figure 5).

The current study will utilize a posttest-only quasi-experimental design. The independent variable of cognitive diversity has two levels: strategic agility and creative problem-solving preferences. The dependent variables are knowledge integration capability and individual contribution with psychological safety acting as a moderating control variable. The student team sample will be divided into two experimental groups receiving one of two treatments (A or B): one group is assessed according to strategic agility and uses the accompanying framework (treatment A) while the second group will be assessed for creative problem-solving preferences and use the accompanying framework (treatment B). These assessments will be administered before a specific design project that the student teams in all treatment groups will complete. At the end of the project, students will complete three surveys: psychological safety, knowledge integration capability, and individual contribution to the team project.

To maximize the validity of the experimental study, certain participant and environmental variables will be controlled for. For example, data on student gender and race will be collected to control for some demographic diversities of student teams. Additionally, the instructional course will be nearly the same for all students in both experimental groups. The same course or curricular shell is used by all faculty and graduate instructors who teach the class, and all students will receive a treatment (either A or B) as part of the natural course flow, thus there will be no motivation for participants to behave abnormally (John Henry effect) (Bärnighausen et al., 2017).

A quasi-experimental design has several advantages over a randomized control-treatment design. For example, subjects "are unlikely to know that outcomes are observed and that they have been exogenously 'assigned' to treatment…groups, reducing the likelihood of biases due to resentful demoralization" (Bärnighausen et al., 2017, p. 25). Also, while randomized control-treatment designs inherently imply invasive selection and treatment routines by researchers on participants (Miller, Smith, & Pugatch, 2020; Sekaran & Bougie, 2016; Gay et al., 2012), quasi-experimental studies are typically conducted in "real-life systems with routinely available resources and in every-day delivery contexts" (Bärnighausen et al., 2017, p. 24). But in a posttest-only design, there are some weaknesses to this research approach. It is true that a posttest-only approach does eliminate bias through the testing effect (pretest scores prime desired behavior), but there remains the risk of participant variables interfering with the outcome results thus contaminating the true effect of the treatment (Sekaran & Bougie, 2016).

However, there are some actions that can be taken to minimize the risk and some limitations that cannot be helped. Knowledge integration capability and individual team contribution cannot be assessed before the team has done any work together, thus a pretest of these variables would be invalid and inappropriate. Whereas controlling for some of the participant variables of surface-level (i.e., gender and race) diversity, as mentioned previously, can ameliorate the risks associated with posttest-only designs.

Gay, Mills, and Airasian (2012) have argued that there are two major problems in educational research that need to be accounted for to ensure validity of study results. The first is a "lack of sufficient exposure to treatments" (p. 252) and secondly, is "failure to make the treatments substantially different from one another" (p. 252). There are several measures that will be undertaken to address these problems.

Of note, students need to not only understand and interpret their results for themselves, but also in the context of a team. To ensure there is effective use of the assessment results and the associated cognitive diversity models on a personal and team level (sufficient exposure to treatments), students will devise a team charter after being assessed for cognitive diversity. The process of creating a team charter, as aided by the worksheet in Appendix B, will encourage students to discuss the strengths, weaknesses, and opportunities they see from their team diversity. Also, based on what they have just learned about one another, they will set some general ground rules for how they will work together over the course of their next project. The inclusion of a team charter offers some level of assurance that the treatment of visualizing and understanding team cognitive diversity has been applied across all treatment groups in an effective and adequate manner.

To then account for the failure of substantially different treatments, the theoretical foundations, visual models, and frameworks for application for the two variables of cognitive of diversity are significantly different. While the process the student participants will use to receive the treatment (i.e., assessment, results, team charter, etc.) are similar enough to eliminate some procedural confounding variables, the language and terminology and potential ways in which students will perceive themselves and their team members should be different. *AEM-Cube* frameworks focus on ethological behaviors and the assessment itself is not to be used as a type-indicator. Whereas *FourSight* results use type-indicator language (e.g., "You are a clarifier" or "You have a high clarifying preference") and draw heavily on psychological behaviors related to creative processes. Therefore, for these and many other reasons described in Chapter 2, the treatments themselves are sufficiently different to compare effectively.

There may be some concerns for the short time frame in which the intervention is conducted. However, many researchers have made calls for varying temporal constraints on team functions to elucidate team dynamics across time (Humphrey & Aime, 2014; Srikanth et al., 2016; Mathieu et al., 2019). A concern for cognitively diverse student teams is integrating knowledge assets over a shorter time period (Huber & Lewis, 2010; Cronin & Weingert, 2007; Heath & Staudenmayer, 2000), thus implementing a design task that is of moderate size and within a relatively compact time frame of nearly four weeks could better answer RQ3 and RQ6 as to what frameworks ameliorate this important and related issue and contribute to the team literature.

In conclusion, the approach for analysis for the proposed study has several advantages in eliminating selection bias, participant testing effects, and other behavior priming that would otherwise negatively influence this study. The posttest-only approach is a limitation imposed by the variables under investigation but is not without merit. The advantages of conducting research with the routine systems of an undergraduate course on design thinking (a quasi-experimental design) ensures some level of consistency and added validity to the outcome results. Therefore, this study design will help to discover answers to the research questions of interest.

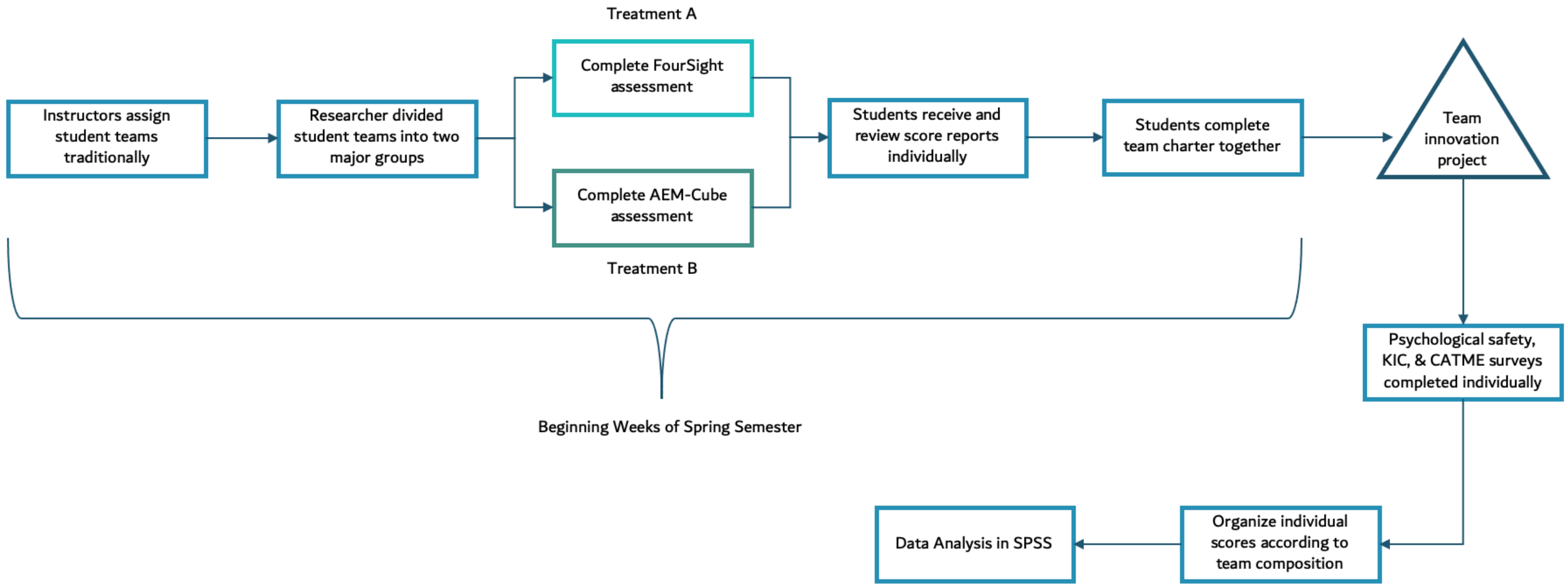

Figure 5. Flow Chart of Methodology

Note. This flow chart displays both the process and general timing of key actions made by the researcher as part of the research design. The triangle is used to signify a checkpoint of time that determines the rest of the process.

3.3 Population and Sample

The generalizable population is all undergraduate students enrolled in a freshman undergraduate design thinking course at a large research university in the Midwestern United States. The design thinking course is a required class for those students who have chosen to pursue majors within the engineering and technology colleges of the university.

The design thinking course—named TECH 120—focuses on introducing technology and engineering students on tackling real-world, global challenges using engineering design and design thinking principles with a special emphasis on human-centered design. There are several design projects of varying lengths and complexity included in the course that provide students opportunities for acquiring both a breadth and a depth of knowledge in understanding the process of designing solutions to wicked challenges as well as working within in a team to accomplish such open-ended design work. The study will take place after Project 1, which is a very brief design thinking project at the beginning of the semester, and over the course of Project 2, which is a 4-week design thinking project that spans the beginning-to-middle portion of the course.

While there are many courses in design thinking on the selected campus, the TECH 120 course has as its aim and major learning outcomes that students will learn to effectively work within a team to implement design thinking processes and principles (see Appendix C). This learning outcome best aligns with the purpose of this study and thus, TECH 120 was selected as the context and setting for the proposed research.

Furthermore, the course design offers some advantages that contribute to the validity of the outcome results. The course is taught by graduate students and faculty that follow the same curricular or course shell (e.g., all instructors are teaching nearly the same thing on the same day). The instructors meet weekly to share knowledge, be trained and mentored by the course coordinators, and synchronize their teaching strategies. Therefore, these routine systems provide a similar experience for all students across all experimental groups thus helping to facilitate the validity of the quasi-experimental design approach.

The projected enrollment of students was around 500 undergraduates, which, after creating teams of approximately 3-4 members, results in approximately 125-129 individual teams. The data collection was conducted individually but analyzed at the team level. The sample then of approximately n=125 student teams is a better fit for robust statistical analysis with results that of greater generalizability. However, not all students participated as some did not complete all parts of the treatment (i.e., assessments, team charter, and surveys). Therefore, only those teams that completed all required assessments and surveys were able to be considered for analysis. The benefit then of drawing from this larger sample of students is the probability of still evaluating a sizeable number of student teams.

The tasks performed by the participants (completing two assessments and three surveys) will be given small point values and incorporated into the structure of the class. As previously stated, students always have the option of whether to complete assignments or not, but by making these tasks required assignments with points, this increases the likelihood that most if not all students will participate.

3.4 Variables

The independent variable of cognitive diversity for this study will be divided into two levels: *strategic agility* as measured by the *AEM-Cube* assessment and *creative problem-solving preferences*, as measured by the *FourSight* assessment. Both will be collected as scaled, continuous data.

The dependent variables of this study will be *knowledge integration, psychological safety,* and *team member contribution* as measured through three separate survey measures. These instruments result in scaled, continuous data.

Psychological safety has been reported in recent research (Reynolds & Lewis, 2018; Edmondson, 2019) as a moderating variable for cognitively diverse teams to achieve desired results. All teams experience conflict, but the logical entailment holds that even teams that are cognitively diverse will experience conflict and possibly even more so. Such conflict can arise from a range of behaviors such as miscommunications, failures, and risks to name a few. Reynolds and Lewis (2018) found that cognitively diverse teams struggled to adapt to the failures of others because there was a lack of psychological safety. In this proposed study, the researcher will measure and account for psychological safety to moderate the relationship of cognitively diverse teams and their knowledge integration and team member contribution.

3.5 Instrumentation

To quantify and measure the independent and dependent variables aforementioned in the previous section, various instruments will be used in the course of this study.

3.5.1 Strategic agility

The *AEM-Cube* assessment was developed by Robertson (1999) as a management tool to help leaders assess individuals, teams, and organizations in order to understand how organizational members respond to change, an operational construct defined as strategic agility. As described in Chapter 2, strategic agility is comprised of three major components, each drawn from unique theoretical backgrounds in human and animal behavior: human- and matter-attachment, exploration- versus optimization-orientation, and one's management of complexity (Robertson, 1999, 2005; Robertson and Schoonman, 2013).

The *AEM-Cube* is a management tool utilized by Human Insight Ltd. for over 20 years, and is gaining greater attention (Reynolds & Lewis, 2017, 2018). What has been documented of the instrument's validity does show it to be robust in team and organizational settings (Robertson & Schoonman, 2013). Across the three scales of measurement (attachment, exploration, management of complexity), however, there is strong internal reliability: Attachment □=0.88, Exploration □=0.92, and Management of Complexity □=0.88 (Robertson & Schoonman, 2013, p. 17).

AEM-Cube is an electronic self-report assessment with 48-questions where respondents must use a slider to move a button across a polarity (e.g., I like to tackle new frontiers vs. I like to work with what is proven), resulting in a 10-point scale. The assessment takes an average of 20 minutes to complete.

The assessment has mostly been administered to teams and organizational leaders as a consulting tool (Robertson & Schoonman, 2013). The method for administration in the proposed study is not inconsistent with the placement of the instrument in the life cycle of a project though being used in an educational setting will be somewhat unique in published research (see Reynolds & Lewis, 2017).

3.5.2 Creative problem-solving preferences

The *FourSight* assessment was originally developed by Puccio (1999) to "examine the link between the Creative Problem-Solving process and individual [preferences]" (p. 172). This assessment is unique because it identifies four major stages and/or preferences for the Creative Problem-Solving model developed by Osborn (1953), which has been widely used since. The four stages are: Clarifying, Ideating, Developing, and Implementing. The respondents who are scored and have a high preference for any one of the stages is identified both by the noun form (e.g., a "Clarifier" or "Ideator," etc.) as well as the verb form (e.g. "a person with a high Developing preference," etc.).

The *FourSight* assessment has been validated over 20 different studies over the past twenty years (Puccio, Acar, Miller, & Thurber, 2020). Puccio and Acar (2015) evaluated the reliability of Version 8.1 of the assessment, which is the most current and will be the version used in the proposed study, and found that the assessment has a consistent and relatively good internal reliability across the four major preferences: Clarifier □=0.78, Ideator □= 0.82, Developer □= 0.78, and Implementer □= 0.75 (see Puccio et al., 2020, p. 5). Through the multitude of studies (Puccio et al., 2020) and the recent evaluation of the instrument's internal reliability (Puccio & Acar, 2015), it can be reasonably assumed that this is a strong and valid measure of creative problem-solving preferences.

The *FourSight* assessment is an electronic 36-question, self-report assessment that has answers in a 5-point scale ranging from "Not like me at all" to "Very much like me." The instrument can be completed in an average of ten minutes.

This assessment has been administered to young children (Gurak-Ozdemir, Acar, Puccio, & Wright, 2019), working adults (DeCusatis, 2008), and university students (Puccio, 1999). Generally, it has been administered at the beginning of a course (Puccio, 1999) or before team formation (DeCusaits, 2008). Jones, Puccio, & Mentzer (In-preparation), however, are currently attempting a repeated measures methodology where the assessment is used at the beginning and end of student training in design thinking. Therefore, the methodology for the proposed study is consistent with the previous methods and administrations of this assessment.

3.5.3 Psychological safety

There have been various survey measures created to demonstrate the robustness of psychological safety as a viable construct (Edmondson, 2019). The surveys are typically self-reported questionnaires that range from three (Tucker, Nembhard, & Edmondson, 2007) to seven (Edmondson, 1999) items. The survey to be used in the proposed study will be the original seven-item survey from Edmondson (1999) that has a Cronbach Alpha of □=0.82 for internal reliability. All other psychological safety surveys have been adaptations of this instrument (Edmondson, 2019), but for the purposes of this study no modifications will be necessary. The survey can be used with a 5- or 7-point Likert scale ranging from "Strongly Disagree" to "Strongly Agree" with equal reliability (Edmondson, 2019), however, for the proposed study, the 5-point Likert scale will be used. The survey will take no more than 5 minutes to complete.

Psychological safety has been studied in a wide range of settings (Edmondson & Lei, 2014) using various methods. Edmondson's (1999) 7-item questionnaire had been used to study 50 teams in a manufacturing company across various departments, such as sales, production, new product development, and management. It has been used in various educational and work settings since (see Edmondson, 2019; Edmondson & Lei, 2014). However, this survey has mostly been used an assessment of a current culture amongst a team. In the proposed study, the survey will be administered at the end of the design project to give the student teams an opportunity to work together.

3.5.4 Knowledge integration capability

Knowledge integration is a process, not necessarily an outcome (Marks et al., 2001). Therefore, measuring the *capability* for knowledge integration is the goal rather than evaluating distinct contributions and their assimilation into a single team product. Given that perspective, Leathers (1972) developed a measure to understand the quality of communication in teams as an indication of their integration of knowledge assets. A similar instrument was designed by Hoegl and Gemuenden (2001), specifically for teamwork quality in the context of innovative tasks. Gardner et al. (2012) adapted the previous measures to create a *Knowledge Integration Capability (KIC)* measure. Gardner et al. (2012) worded the items to specifically analyze the communication processes used by the team that facilitate effective integration of knowledge assets.

The KIC is a self-reported 10-item survey using a seven-point scale ranging from positive through neutral to negative. Example items include “Communications within our team were: Relevant—Neutral—Irrelevant” and “Communications within our team were: Supportive—Neutral—Inconsiderate.” Appendix A provides the exact of each of the items. Factor analysis of the items was conducted to confirm that “all items loaded into a single factor” (Gardner et al., 2012, p. 1007) indicating a reliable measure of the construct.

The individual results can be averaged to create a single score per team. Gardner et al. (2012) did so while achieving high reliability, with a Cronbach’s Alpha of □ = 0.95. In the proposed study, the researcher will replicate Gardner et al.’s (2012) averaging of individual scores for a total team score.

3.5.5 Individual contribution

The Comprehensive Assessment of Team Member Effectiveness (CATME) measures student effectiveness across five major categories: contributing to team’s work, interacting with teammates; keeping the team on track; expecting quality; and having relevant knowledge, skills, and abilities (Loughry et al., 2007). The assessment was developed under several grants from the National Science Foundation (CATME Research, 2020) and has been used in a variety of management and engineering education programs throughout the United States (Loughry et al., 2007; Loughry et al., 2014; Ohland et al., 2012; Layton, Loughry, Ohland, & Ricco, 2010; Loignon et al., 2017). The CATME instrument has proven to be reliable in measuring team member contribution (□ = 0.90), as well as in the other categories (Loughry et al., 2007; Loughry et al., 2014). The validity of the CATME instrument has been evident through its wide adoption in various educational settings.

The assessment has up to 87 items that can be used to measure 29 specific types of team member contribution with 3 items each (Loughry et al., 2007), though not all 87 items need be used in a single setting (the TECH 120 course, for instance does not require the students to answer all 87 items each time). It can be used in a Likert scale format or in a web-based version using a Behaviorally Anchored Ratings Scale (BARS) (Ohland et al., 2012). The web-based version is already utilized in the TECH 120 course and will therefore be used in this study. However, only the scores under the “contributing to team’s work” category will be used in the final analysis as the relationship of team member contribution among the other variables under study best aligns with the purpose of the proposed research.

3.6 Methods for Data Collection and Analysis

3.6.1 Data collection

Near the beginning of the Spring semester the students in the TECH 120 course, will be organized into groups based on academic major. This is a traditional component to the class. Just prior to the second major design project in the design thinking course (around week three of the semester), the student teams will be divided into two distinct groups. Half of the student teams were given an assignment to complete the *AEM-Cube* assessment while the other half were assigned to complete the *FourSight* assessments. A small point value was associated with the completion of the assessments which is normal classroom protocol as motivation for the students to complete the assessments. As there are several graduate course instructors spanning several sections, each instructor is assigned two sections they will teach. Therefore, to ensure randomization and reliability in the results, the divisions were made among the two sections overseen by each instructor such that every instructor had one section of students treated using *AEM-Cube*, the other with *FourSight*.

The students were reminded in the class assignment that the results of these assessments could potentially assist the students to learn more about themselves and about their future teammates that would help them work better and possibly develop more innovative solutions. Therefore, the completion of these assessments would be to the benefit of the students both on a grade standpoint and from a learning experience perspective as well.

As the students completed the assessments, their results were stored in the associated assessment databases (*AEM-Cube* and *FourSight* each have a facilitator account database where the scores will simultaneously be delivered to the researcher as well as emailed to the individual student). The results were then received by the students in two digital, educational formats. *AEM-Cube* has 10-minute (or less) videos that explain the accompanying PDF of results and the implications for use within a team context. *FourSight* offers a PDF of results as well as audio-dubbed PowerPoint presentations that explain the results and implications for use within a team context. The students, by assignment, were required to view the results (PDF and/or video and/or PowerPoint) for the next step in the assignment process.

The students met as a group to discuss their results and create a team charter (see Appendix B) to help them apply the suggested framework (be it *AEM-Cube* or *FourSight*) to their work as a team. The team charters were submitted to the instructors and the researcher. The students then completed "Project 2", an approximately 4-week innovation project where student teams practiced their newfound skills in design thinking to design a novel solution to a technological problem.

Following the completion of Project 2, student teams completed three surveys, one of which has customarily been used in the class. The first survey is the 7-item self-report psychological safety survey through an online service. The second survey was the *Knowledge Integration Capability (KIC)* instrument (10-items, self-report), also administered through an online service. The results for these two surveys were received by the researcher through the respective online services. The final survey was the CATME group assessment where students reported on their own contribution as well as the perceived level of contribution of their fellow team members. This data was collected through the CATME system and given to the researcher by the course coordinators. Additionally, demographic data, specifically the gender and race of each student participant, was provided to the researcher by the university's registrar. At this point all data collection for the purposes of the proposed study was complete.

3.6.2 Data analysis

All survey data was exported and recorded in the Excel sheet along with the other individual student data from the *AEM-Cube* and *FourSight* assessments. Both the KIC and psychological safety scores were reported as individuals but needed to be averaged to create a cumulative score for both items for each team. This approach is consistent with previous uses of these instruments (Gardner et al., 2012; Edmondson, 2019).

The results specifically regarding team contribution were extracted from the CATME survey results. All team members reflected and rated their own and their team members' level of contribution. The average of the team's combined total scores was used to enable the researcher to see the perceived level of team member contribution for a single team. This also created a single quantifiable variable for team member contribution.

A team score was also needed for the *AEM-Cube* and *FourSight* assessment results. This would allow for a representation of the level of spread of diversity (low spread = not so diverse; high spread = very diverse) across the various personal and team results. For the *FourSight* data, the standard deviation of the number of high preferences in a team was used to create a *FourSight Team Score*. For the *AEM-Cube* results, a similar method used in the Reynolds and Lewis (2017) study for calculating a single team score representing the level of diversity in a given team was used. In summary, there are three scored areas: attachment, exploration, and management of complexity. The researcher calculated the individual scores for attachment on a team (for example) to find the standard deviation for attachment and so on for each scored area of a team. Then, the sum of the standard deviations across all three dimensions within a team was used as the final variable called the *Strategic Agility Score.*

As Psychological safety was a control for all statistical analyses undertaken, any considered correlational and analyses of differences must account for a control variable. Additionally, controls for gender and race will be accounted for as well. Thus, parametric Partial Correlation analyses was used to answer RQ1, RQ2, RQ4, and RQ5 as this statistical analysis facilitates the use of continuous independent and dependent variables while also controlling for another. A parametric ANCOVA was used to answer RQ3 and RQ6 independently or simultaneously while controlling for psychological safety.

CHAPTER 4. RESULTS

4.1 Introduction

The purpose of this study was to investigate the relationship and influence of students understanding of their teams' cognitive diversity through two competing frameworks on team knowledge integration capability and member contribution during a 4-week innovation project. This study has utilized a quasi-experimental design with data collection occurring before and after the innovation project. The posttest-only nature of this study (see *Chapter 3: Approach for Analysis*) is in the dependent variables being analyzed: knowledge integration and team member contribution. These variables, along with the moderating variable of psychological safety, could only be measured after the team had completed their work together.

4.2 Data Screening

A total of n=469 students were enrolled in the TECH 120 course with 10 students dropping the course midway through the study, leaving a total of n=459 students that participated—both in the course and in the study in some manner. A total of 129 teams were created with the average team size being between 3 and 4 members (mean=3.56). Only 75 of the 129 teams completed all surveys and assessments. While there are data to study nearly all 129 teams, the nature of the psychological safety survey questions posed an interesting dilemma. These survey questions required individuals to report their personal level of satisfaction, thus if any team member did not fully participate, the team aggregate could be misrepresented. Because analysis is conducted at the team-level, such misrepresentation could result in misleading interpretations of the data. Therefore, our population of n=75 teams were analyzed. Of these 75 teams, 38 completed the AEM-Cube assessment while 37 completed the FourSight assessment.

4.3 Data Preparation: Team Scoring and Preliminary Analysis

Because the analysis to be conducted was at the team level, individual responses across the independent and dependent variables must be aggregated into team-level scores. This was done using different methods. Explanations for how and why these differing methods are noted below.

4.3.1 Strategic Agility Score

The AEM-Cube assessment measures patterns of human thinking and behavior in relation to one's response to change and growth. These three dimensions are Attachment, Exploration, and Management of Complexity. The assessment is divided into three sections with questions relating to each dimension. Answers to questions result in a 6-point scale, 1 equating to one end of a dimension and 6 equating to the other. The total score across each dimension is not merely a sum but is a calculation that takes into account a normative group. Each respondent receives a "total score" for each dimension.

Reynolds and Lewis (2017, 2018), however, did not use the normative group approach. Rather, total scores for each individual were computed by simply taking the sum of each item response within a dimension. This was done to ensure that the sample(s) under analysis could be evaluated as if "self-contained." Then, to investigate the data at the team level, Reynolds and Lewis (2017) calculated the standard deviation of scores across each dimension (e.g., standard deviation of a team's attachment scores, then the standard deviation of the team's exploration scores, etc.) and then added the three standard deviation outputs to create a *Strategic Agility Score.* Therefore, due to the precedence, acceptance, and validity of this method by the research community and AEM-Cube practitioners, the researcher calculated the Strategic Agility Score for each team following this same approach.

4.3.2 FourSight Team Score

FourSight is an assessment that seeks to measure creative problem-solving preferences across four major phases of the problem-solving process: clarifying, ideating, developing, and implementing. Scores in each dimension range from 9-45 with one participant receiving a score for each dimension thereby resulting in a FourSight Thinking Profile™. Figure 6 displays an example FourSight Thinking Profile™ with annotations indicating peak, neutral, and low preferences.

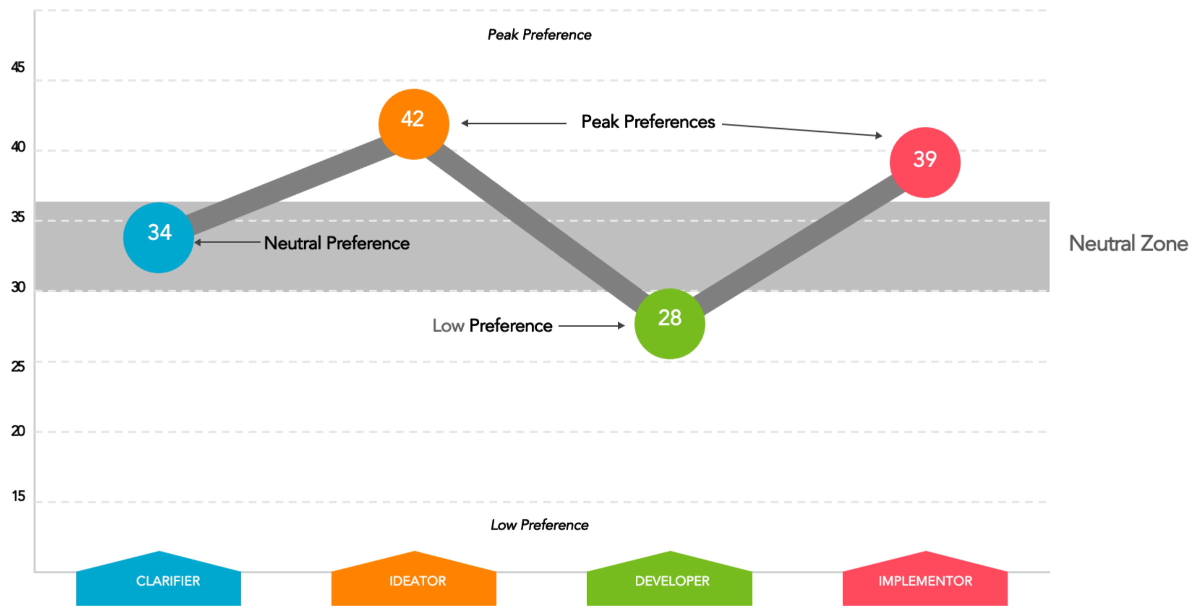

Figure 6. Example of FourSight Thinking Profile™

Note. Peak preferences are above the neutral zone with low preferences below the neutral zone. This is a non-student example provided by the FourSight company and used with permission.

In the FourSight theory, peak preferences are of major interest as these reflect the types of thinking respondents prefer over other types of thinking. They determine the nominal identifiers (used for classification) for the overall FourSight Thinking Profile™ (i.e., in Figure 6, the nominal identifier for this type of profile—where ideating and implementing are peak preferences while clarifying and developing are either neutral or low (or both), is called a "*Driver*"). It is true that the spread between peak and low preferences also impacts behavior, but it is of peak preferences that researchers, educators, and practitioners focus (Puccio & Acar, 2015; Puccio et al., 2018). Therefore, in evaluating a methodology for FourSight team scores, the weight of peak preference—both in theory and praxis—was greatly considered.

The use of a single score representing team diversity has never been used in the extant FourSight literature. Therefore, a methodology to accomplish this task required both adoption and adaptation for where the diversity of peak preferences was weighted above all else.

To identify peak preferences, calculating the neutral zone (see Fig. 6) is critical. An individual profile's neutral zone is calculated by taking the average of the highest and lowest scores and rounding down to the nearest whole number then adding and subtracting 2.5 to create a 5-point neutral zone (representing one standard deviation) (FourSight, 2017). Thus, the high end of this neutral zone is the threshold for "lesser preferences"—anything above it is considered a peak preference (FourSight, 2017). Therefore, the following method was developed, adapting FourSight's (2017) procedure in obtaining peak preference scores (see Figure 7 for an example of these steps):

1. Calculate the upper threshold of the neutral zone for each individual profile in a team
    a. This was done by subtracting the highest score in one's profile by the lowest. Find the middle of the result and subtract the highest score by this number. Finally, add 2.5 to get the threshold.
    b. Example: 37 – 28 = 9. The middle of 9 is 4.5, so subtract 4.5 from 37 (32.5), which is the middle. 32.5 + 2.5 = 35, which is the threshold for this individual's profile. Anything above 35 is a peak preference.
2. Use a binary (0,1) code to indicate which is (1) and is not (0) a peak preference for each individual
3. Take the standard deviation (using the STDEV.P function in Microsoft Excel) of team members across each dimension
    a. For example, take the standard deviation of the clarifying dimension, then the ideating dimension and so forth
4. Take the sum of the four standard deviations to represent the diversity score

Profile	Clarifier	Ideator	Developer	Implementer	Middle	Threshold	Clarifier	Ideator	Developer	Implementer	
Ideator	28	37	31	34	32.5	35	0	1	0	0	
Implementer	36	34	37	39	36.5	39	0	0	0	1	
Finisher	27	24	30	30	27	29.5	0	0	1	1	
Integrator	34	35	36	33	34.5	37	0	0	0	0	
Clarifier	39	37	34	33	36	38.5	1	0	0	0	**Sum**
							0.4	0.4	0.4	0.489897949	**1.6898979**

Figure 7. No. Student Example in Calculating the FourSight Team Score

Note. The standard deviations for each dimension are on the seventh row down on the right-hand side with the sum total on the far right-hand side.

The resulting final FourSight Team Score is an integer between 0 and 2 with scores closer to 0 being teams with more homogenous peak preferences and those closer to 2 showing a greater diversity of peak preferences.

4.3.3 Team Scores for Other Variables

The total team scores for knowledge integration, team contribution, and psychological safety were calculated by simply finding the average. Each of these variables was measured using a relatively similar Likert-scale approach, with knowledge integration on a 7-point scale and team contribution and psychological safety on 5-point scales. The rationale for using averages here was that for the purpose of answering the research questions, the general or average rating of the team according to these variables was sufficient and not without precedent (Gardner et al., 2012; Edmondson, 1999). The goal is not to represent the "diversity" of individual contributions, but of the average level of contribution in a team. Therefore, a more nuanced methodology was not necessary.

To note, the highest possible individual score for knowledge integration is 70 with 10 being the lowest possible with the final average also within this range. While a high average would generally indicate a team with greater knowledge integration capabilities, there is no prevailing literature on how to determine low, medium, and high ranks of knowledge integration capability. The items on the questionnaire are formatted such that participants must choose a number between one and seven. With the number four labeled "neutral", numbers 1-3 represent a range of low knowledge integration capability, while the numbers 5-7 represent a high range of the construct. Because there are ten items on the questionnaire, an individual student's total reporting of team knowledge integration capability is a sum of responses with maximum of 70 and a minimum of ten. Therefore, three categories of low, medium, and high were created for this study based on the questionnaire. Any score reports between 10-30 denote a team with low-level knowledge integration capability while score reports between 50-70 would denote relative agreement that knowledge integration capability levels were high. Teams with knowledge integration capability scores in the 30-50 range would denote a team of medium-level knowledge integration capability.

The highest possible individual score for psychological safety was 35 with 7 being the lowest possible and team averages also reflect this range. Using a 5-point Likert scale ranging from Strongly Agree (represented by the nominal code of 5) to Strongly Disagree (coded as 1), any score 28 and above would denote those individual reports were in relative agreement that their team was psychologically safe. Therefore, the cutoff point of 28 and above was used to determine teams with high psychological safety and those that were not.

The range of individual and team scores for team contribution are from 1 to 5, with a 5 indicating a team that "exceeded all expectations" in contribution while 1 would indicate that no one contributed anything. A report of "3" would denote that a team member met expectations while a report of "4" would denote that a team member both met and exceeded some expectations for individual contribution. Therefore, team averages 4 and above would denote that, in a general sense, team members were both meeting and exceeding some expectations for overall team contribution. In other words, team contribution was high.

4.3.4 Preliminary Analysis

Before analyzing the data to answer the research questions, some preliminary analysis was warranted to first, examine differences in demographic makeup of the two treatment groups and, secondly, ensure normality of variable distributions.

It was crucial that the treatment groups had similar compositions of gender and race that the results could retain some validity. Nearly 62% of Purdue University's undergraduate population identifies as white (Purdue University Division of Diversity and Inclusion, 2019) and the TECH 120 course—the setting for this study—is typically predominantly composed of male undergraduate students (Mentzer, Laux, Zissimopoulos, & Richards, 2016). Therefore, the demographic data received were coded as "white male" or "non-white male" to help provide a simple and accurate view of how much surface-level diversity beyond the norm was present in the course.

A Pearson X^2 test was used to calculate these differences among the variables of surface-level diversity and *Instru_Type*—a nominal variable indicating whether a team participated and completed an AEM-Cube (coded as 1) or FourSight (coded as 2) treatment. Table 1 summarizes the results of the Pearson X^2 test. There were roughly equal numbers of white males in both treatments. While there were five more diverse students assigned to the FourSight treatment, this difference is not significant ($p = .629$). Therefore, it was assumed that an even distribution of more common and minority surface-level diversities were present across the two treatment groups.

Table 1. Results of Chi-Square Test of Independence on Student Demographics

Surface Level Diversity	Instrument Type		Pearson X^2	
	AEM-Cube	FourSight	$X^2 (1) = .233$	p = .629
White Male	82	80		
Non-White Male	49	54		

Note. Instrument Type is a nominal variable indicating whether a team completed AEM-Cube or FourSight treatments

Table 2 is a display of the descriptive statistics of the data of the variables pertaining to this study. The nominal variable *Instru_Type,* as previously defined, identifies whether a team was assigned the AEM-Cube or FourSight assessment. Knowledge integration capability (KIC) has, at first glance, a negatively skewed distribution (-.797). However, using descriptive or population-based (rather than inferential or sample-based) methods to interpret skew, the distribution did not vary significantly from normal. Therefore, all proceeding analyses assumed KIC team scores—as well as other variable distributions—as normally distributed.

Table 2. Descriptive Statistics of Variables

Variable	N	Min.	Max.	Mean	Std. Deviation	Variance	Skewness
KIC	75	48.3750	68.3250	60.3493	4.5598	20.792	-.797
FTS	37	.43301	1.8856	1.2381	.4809	.231	-.216
SAS	38	4.50	52.6197	27.0223	11.4933	132.097	.330
Psych. Safety	75	25.50	34	30.2710	1.9602	3.842	-.210
CATME	75	3.111	4.8750	4.14	.3545	.126	-.303
Instru_Type	75	1	2	1.49	.503	.253	.027

Note. KIC = Knowledge Integration Capability team scores; FTS = FourSight Team Score; SAS = Strategic Agility Score for teams; Psych. Safety = Psychological Safety team scores; CATME = Team Contribution scores; Instru_Type = Nominal variable indicating whether a team completed AEM-Cube (1) or FourSight (2) treatments.

4.4 Analysis

4.4.1 Order of Analysis

The research questions that guide the following analysis are as follows:

RQ1: Is strategic agility correlated with knowledge integration capability when controlling for psychological safety?

RQ2: Is creative problem-solving preference correlated with knowledge integration capability when controlling for psychological safety?

RQ3: Which framework (strategic agility or creative problem-solving preference) helps students score higher in knowledge integration capability when controlling for psychological safety?

RQ4: Is strategic agility correlated with team member contribution when controlling for psychological safety?

RQ5: Is creative problem-solving preference correlated with team member contribution when controlling for psychological safety?

RQ6: Which framework (strategic agility or creative problem-solving preference) helps students contribute equally across team members?

The first three questions focus on knowledge integration while the other three focus on student contribution. Therefore, the following analysis will be divided into two parts, the first dealing with the former focus while the second part dealing with the latter.

4.4.2 Knowledge Integration

Question One. To address the first research question regarding whether strategic agility and knowledge integration capability were related without controlling for psychological safety. Figure 8 displays a scatterplot of this relationship. Visually, there is no slope indicative of a significant relationship. Additionally, after conducting a parametric Partial Correlation to test the relationship strategic agility and knowledge integration capability where psychological safety was a control, the relationship was found not to be statistically significant ($p = .151$) (see Table 3).

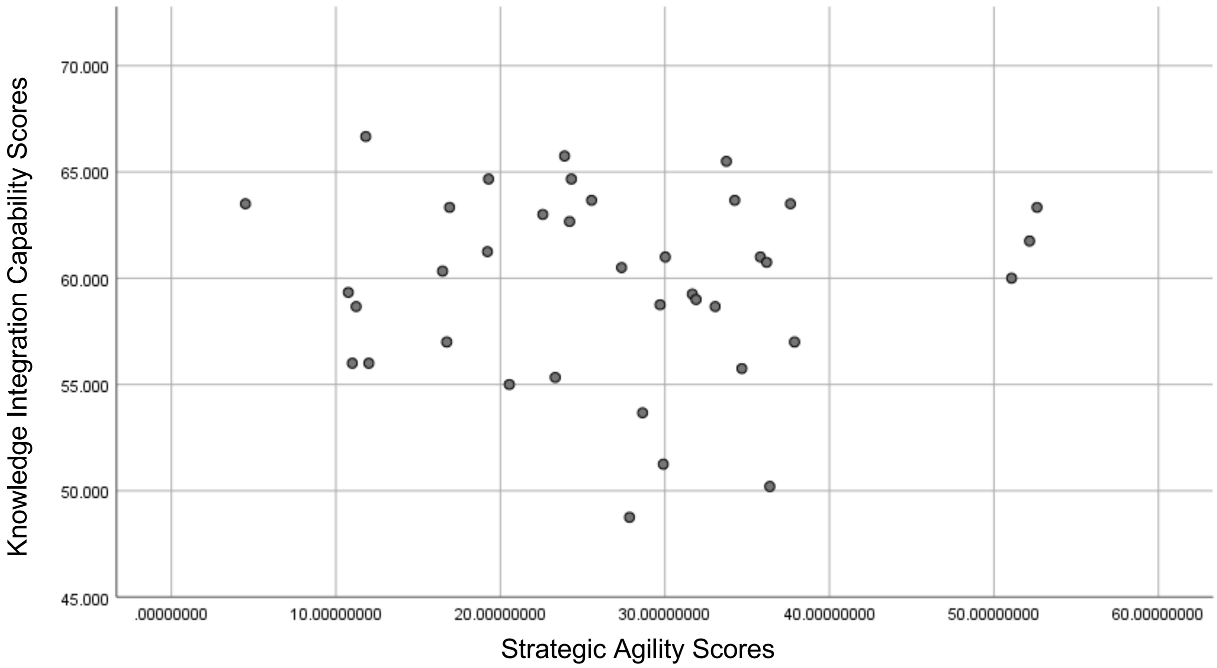

Figure 8. Scatterplot of Relationship Between Strategic Agility Scores and Knowledge Integration Scores Without Controlling for Psychological Safety

Note. The moderating variable of psychological safety is not present in this scatterplot.

Table 3. Results of Partial Correlation for Research Question 1

CONTROL VARIABLES	OTHER VARIABLES		STRATEGIC AGILITY SCORES	KNOWLEDGE INTEGRATION CAPABILITY SCORES
PSYCHOLOGICAL SAFETY	Strategic Agility Scores	Correlation	1.000	-.241
		Significance (2-tailed)		.151
		Degrees of Freedom	0	35
	Knowledge Integration Capability Scores	Correlation	-.241	1.000
		Significance (2-tailed)	.151	
		Degrees of Freedom	35	0

Question Two. Similar to RQ1, a first correlational test with a scatterplot was used on the independent and dependent variables without the standard covariate of psychological safety. In this case, the independent variable was creative problem-solving preferences (FourSight Team Scores) and team knowledge integration capability. Figure 9 is the resulting scatterplot with no apparent slope. A parametric Partial Correlation analysis was computed with psychological safety as the control. Table 4 displays the results, which indicate that there is no statistically significant relationship (p=.542) between creative problem-solving preferences (FourSight Team Scores) and team knowledge integration capability when controlling for psychological safety.

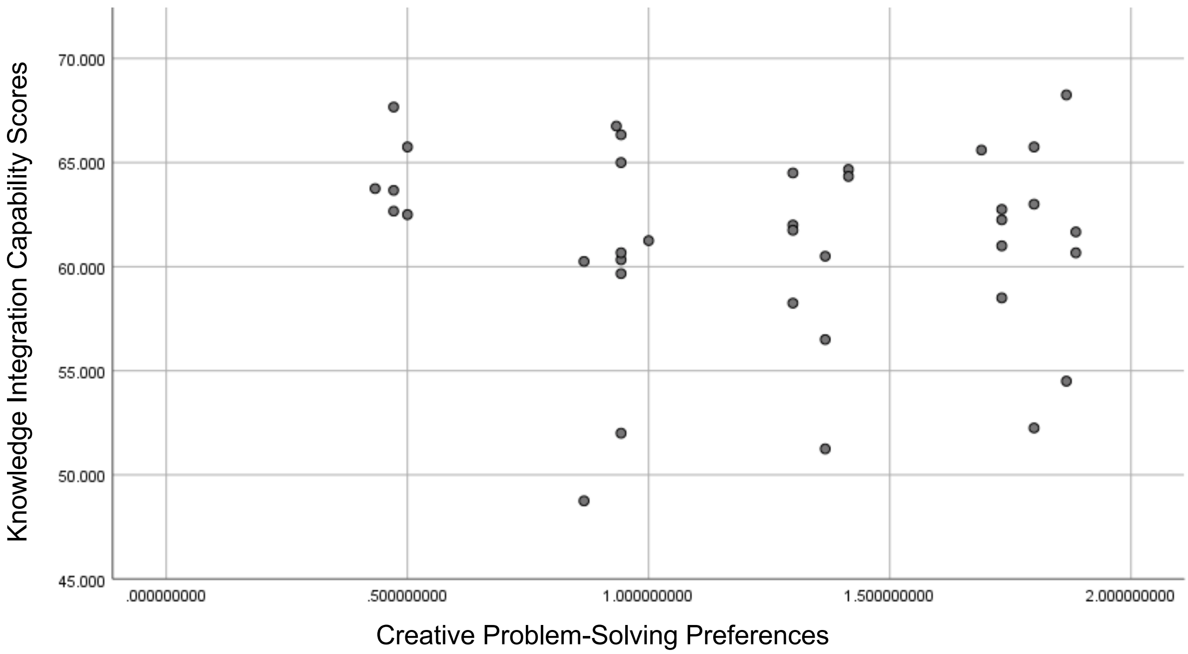

Figure 9. Scatterplot of Relationship Between Creative Problem-Solving Preferences and Knowledge Integration Scores Without Controlling for Psychological Safety

Note. The moderating variable of psychological safety is not present in this scatterplot.

Table 4. Results of Partial Correlation for Research Question 2

CONTROL VARIABLES	OTHER VARIABLES		KNOWLEDGE INTEGRATION CAPABILITY SCORES	CREATIVE PROBLEM-SOLVING PREFERENCES
PSYCHOLOGICAL SAFETY	Knowledge Integration Capability Scores	Correlation	1.000	-.105
		Significance (2-tailed)		.542
		Degrees of Freedom	0	34
	Creative Problem-Solving Preferences	Correlation	-.105	1.000
		Significance (2-tailed)	.542	
		Degrees of Freedom	34	0

Question Three. A parametric ANCOVA was used to determine which framework (strategic agility or creative problem-solving preference) helps students score higher in knowledge integration capability when controlling for psychological safety. Table 5 displays the output of the ANCOVA from SPSS. There are no significant differences among frameworks in terms of their knowledge integration capability (p=.233) after controlling for psychological safety. Interestingly, however, psychological safety was a significant covariate F (1, 75) = 56.850, p<.001.

Table 5. ANCOVA Output for Influence of Differences in Frameworks on Team Knowledge Integration Capability When Controlling for Psychological Safety

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	703.323[Note]	2	351.661	30.313	.000
Intercept	61.542	1	61.542	5.305	.024
Psych. Safety	659.520	1	659.520	56.850	>.001
Framework Type	16.769	1	16.769	1.445	.233
Error	835.278	72	11.601		
Total	276001.209	75			
Corrected Model	1538.600	74			

Note. R Squared = .457 (Adjusted R Squared = .442).

4.4.3 Team Member Contribution

Question Four. As was completed with RQ1 and RQ2, a scatterplot was created to visualize the relationship of strategic agility scores and team member contribution without the influence of the moderating variable of psychological safety. Figure 10 is a display of the scatterplot. As can be seen, there is no slope indicative of a salient relationship between these two variables. A parametric Partial Correlation, where psychological safety was a covariate, was used to test the relationship between strategic agility and team member contribution. The results show that there is no statistically significant relationship between strategic agility scores and team member contribution when controlling for psychological safety (p=.108) (see Table 6).

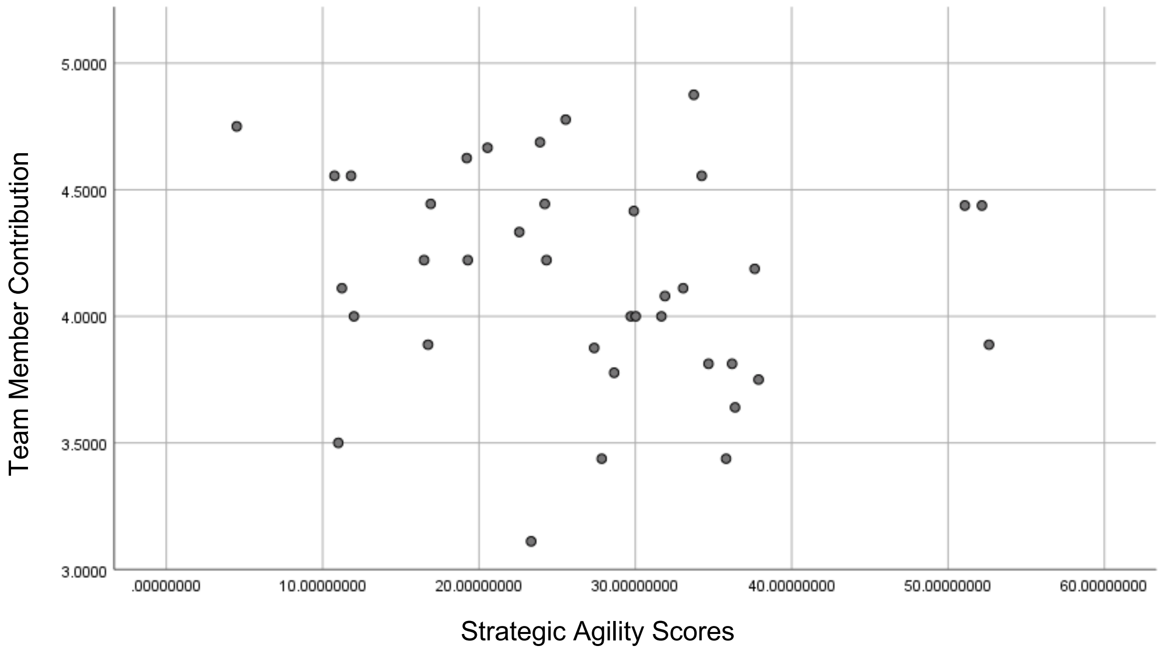

Figure 10. Scatterplot of Relationship Between Strategic Agility Scores and Team Member Contribution Without Controlling for Psychological Safety

Note. The moderating variable of psychological safety is not present in this scatterplot.

Table 6. Results of Partial Correlation for Research Question 4

CONTROL VARIABLES	OTHER VARIABLES		STRATEGIC AGILITY SCORES	TEAM MEMBER CONTRIBUTION
PSYCHOLOGICAL SAFETY	Strategic Agility Score	Correlation	1.000	-.269
		Significance (2-tailed)		.108
		Degrees of Freedom	0	35
	Team Member Contribution	Correlation	-.269	1.000
		Significance (2-tailed)	.108	
		Degrees of Freedom	35	0

Question Five. A scatterplot was generated to visualize the relationship of creative problem-solving preferences (as measured by FourSight) and team member contribution without controlling for psychological safety. Figure 11 is a display of that scatterplot and there is no indication of a significant relationship. A parametric Partial Correlation was used to determine the relationship of the creative problem-solving preferences and team member contribution when controlling for psychological safety. The results indicate that there was no statistically significant correlation (p=.468) (see Table 7).

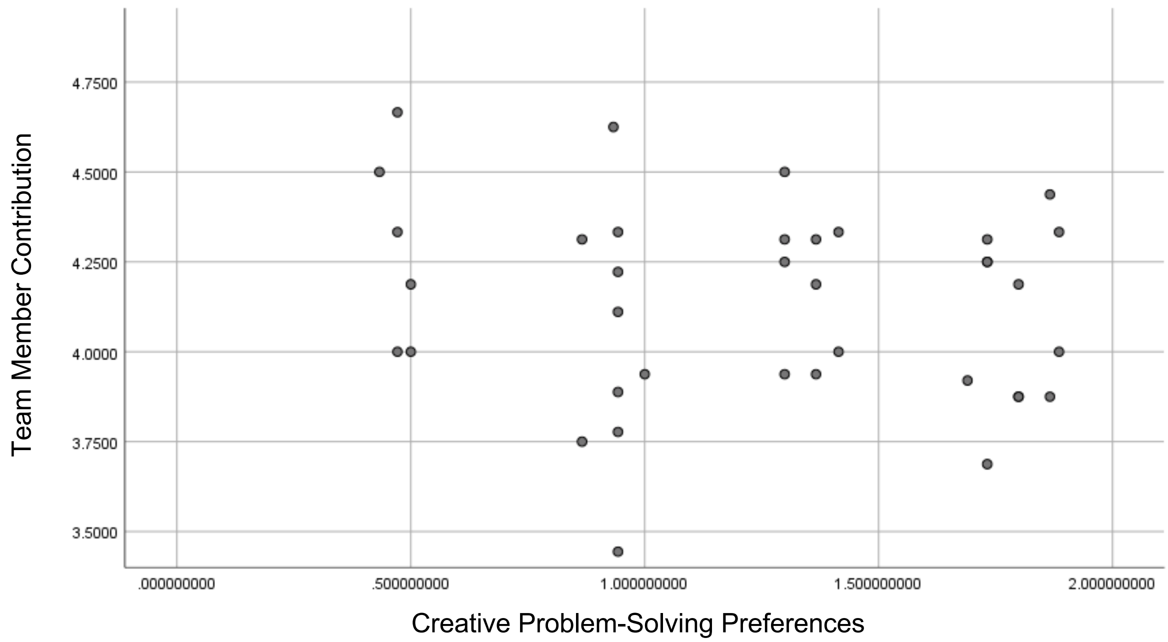

Figure 11. Scatterplot of Relationship Between Creative Problem-Solving Preferences and Team Member Contribution Without Controlling for Psychological Safety

Note. The moderating variable of psychological safety is not present in this scatterplot.

Table 7. Results of Partial Correlation for Research Question 5

CONTROL VARIABLES	OTHER VARIABLES		TEAM MEMBER CONTRIBUTION	CREATIVE PROBLEM-SOLVING PREFERENCES
PSYCHOLOGICAL SAFETY	Team Member Contribution	Correlation	1.000	-.125
		Significance (2-tailed)		.468
		Degrees of Freedom	0	34
	Creative Problem-Solving Preferences	Correlation	-.125	1.000
		Significance (2-tailed)	.468	
		Degrees of Freedom	34	0

Question Six. This research question mirrors RQ3 in many ways except the main effect for which framework (strategic agility or creative problem-solving preference) helps students score higher in team member contribution when controlling for psychological safety. Therefore, a parametric ANCOVA was determined to answer this question (see Table 8 for results). The results from this test show that there were no significant differences among frameworks in terms of their team member contribution after controlling for psychological safety (p=.581). However, as was the case in the results of RQ3, psychological safety was a significant covariate F (1, 75) = 11.773, p=.001.

Table 8. ANCOVA Output for Influence of Differences in Frameworks on Team Member Contribution When Controlling for Psychological Safety

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	1.312[Note]	2	.656	5.911	.004
Intercept	1.322	1	1.322	11.906	.001
Psych. Safety	1.307	1	1.307	11.773	.001
Framework Type	.034	1	.034	.307	.581
Error	7.992	72	.111		
Total	1294.791	75			
Corrected Model	9.304	74			

Note. R Squared = .141 (Adjusted R Squared = .117).

4.5 Summary

A total of n=75 student teams were studied. Across six research questions, four Partial Correlations and two ANCOVAs were used in effort to answer these questions. The level of student team diversity—whether described in terms of creative problem-solving preferences or in terms of strategic agility—are not related to their knowledge integration capability or team member contribution when controlling for psychological safety. Of the two frameworks used to guide teams in understanding their cognitive diversity, there is no significant difference in team knowledge integration capabilities and team member contribution.

CHAPTER 5. DISCUSSION

This study investigated the influence and relationship of two cognitive diversity frameworks on student design team knowledge integration capabilities and team contribution among seventy-five (75) student teams in Purdue's Tech 120: Design Thinking in Technology course. Using a posttest-only quasi-experimental design, data were collected over a period of six weeks using online-based assessments and surveys. This chapter provides a summary of the findings and limitations of the study and concludes with recommendations for future research.

5.1 Conclusion

Six research questions guided the researcher in gathering data and conducting statistical analyses. Four of the research questions (RQ1, RQ2, RQ4, and RQ5) were correlational while the two remaining questions (RQ3 and RQ6) investigated differences among cognitive diversity frameworks on knowledge integration capability and team contribution. The results show that knowledge integration capability scores were equally high among teams of varying levels of cognitive diversity between the two instruments. Team member contribution scores were, also, equally high among teams of varying levels of cognitive diversity between the two instruments. Interestingly then neither knowledge integration capability nor team member contribution were correlated with variances in cognitive diversity. Amid these results, psychological safety was a significant moderating variable, which is consistent with previous research in team settings (Edmondson & Lei, 2014; Rozovsky, 2015; Duhigg, 2016).

The averaged total scores for psychological safety, knowledge integration capability, and team contribution were high. The distributions for these variables were normal, but on the high end of their respective scales (for example, the lowest psychological safety score, was a 25.5 on a scale that has a range of 7 to 35; knowledge integration capability, on a scale with a range of possible scores between 10 and 70, had a minimum score of approximately 48.37). This may be credited to the psychological phenomenon known as the superiority illusion, where individuals believe they are above the average when it is quite impossible for everyone to be so (Hoorens, 1993), but there may be more positive explanations than this that are worth considering.

First, is the nature of the class environment in which the study took place. The course heavily relies on design thinking methodologies as embraced and defined by the Stanford d.School and IDEO. This design thinking framework and curriculum is inherently collaborative with flattened hierarchies and chosen problems requiring a great deal of input and effort from each team member (IDEO, 2021). Therefore, this supportive and collaborative environment may have been a confounding (and explanatory) variable in the results of this study—meaning, the course may have done exactly what it was intended to do in terms of providing a positive team experience. Previous student team studies investigating knowledge integration capability were conducted in business courses where classroom environments may have had more competition, thus potentially more interpersonal conflict, than the contextual environment of this study.

A second possibility for these high scores may be the rather unique combination of activities utilized in the intervention itself. The "treatment" undergone by each student, and therefore each student team, consisted of three parts. The first was that they complete one of two possible cognitive diversity assessments, which would result in a score and visualization of their unique cognitive preferences. Secondly, they participated in a short educational presentation (no more than 10 minutes) where their score was explained in the context of the associated theoretical framework by which their results were derived. And thirdly, students created a team charter where they brought their results and discussed strengths, weaknesses, and expectations for behavior in their work together. This tri-part or tri-fold treatment was developed to ensure that the cognitive diversity frameworks were well understood and relied upon by the students so that the research questions (particularly RQ3 and RQ6) could be tested. However, maybe, in simple terms, the intervention worked too well. Just as with high tide all ships in the harbor are lifted, this intervention may have "lifted" all student teams, creating a ceiling effect. Thus, this thorough treatment may be another confounding variable in the results of this study. More on this subject will be discussed in the "Recommendations for Future Research" and "Recommendations for Practice" sections.

Finally, a third possible explanation for the high scores on the dependent variables could be in the sampling of the study. Only the teams that completed all activities within the assigned treatment (n=75) were used in the final analysis. There were a remaining 54 student teams unanalyzed that had incomplete data—i.e., some students submitted survey responses while others did not and so forth. These 54 student teams may have been the poor functioning teams (which could be implied by the fact that they could not rally their other teammates to complete their assignments) that would have helped to add variation to the current study results. However, all these possibilities, no matter how likely, are not certain and further research as to why all student teams performed so effectively and so well is needed.

The extant literature on team diversity—be it surface-level, functional, or deep-level diversity—is greatly burdened with contradictions (Mathieu et al., 2019; Srikanth et al., 2016; Mathieu et al., 2014; Tshetshema & Chan, 2020). Due to consistent divergent findings, there are serious questions as to the efficacy of diversity in teams. Unfortunately, the findings of this study only seem to complicate the debate. In past studies, diverse student teams have struggled to integrate the knowledge assets scattered among their team members (Dahlin et al., 2005; Klein et al., 2011; Harrison et al., 2002) and this, and other necessities of collaboration, diminish over time as deep-level differences are exposed (Harrison et al., 2002; Srikanth et al., 2016). However, according to the findings of this study, the student teams appeared to not experience these negative effects. Rather, teams with widely distributed and contrasting deep-level differences were able to integrate knowledge assets and enjoy high levels of team contribution similar to more homogenous teams. And while this is a very positive and encouraging finding, it contributes another paradoxical view on cognitive diversity in student teams that needs further research.

Therefore, the major conclusions of this study are that while neither the FourSight or AEM-Cube frameworks for cognitive diversity were more effective in raising student knowledge integration capability or overall team contribution, these frameworks did not negatively impact the student experience; high levels of psychological safety were maintained among both more homogeneous teams and those that were more heterogeneous; and higher levels of knowledge integration capabilities and team contribution were achieved by students in varying degrees of diversity of creative problem-solving preferences and strategic agility. The students reported that the processes by which these teams integrated their knowledge assets and solicited the contribution of their team members was both positive and effective.

5.2 Recommendations for Practice

Based on the results of this study, the following section contains some recommendations for future practice in design education.

Educators will continue to assign and incorporate group/team work into their courses. Class or coursework that specifically tackles complex challenges—sometimes termed "wicked problems" (Rittel & Webber, 1973)—ought to cultivate and encourage team diversity on the cognitive level. The FourSight and AEM-Cube assessments provide user-friendly, theoretically based experiences both in testing and in understanding one's results in terms of cognitive diversity in team settings. This study did not distinguish one assessment (and therefore theoretical framework) as better or worse than another as student teams using either assessment performed equally as well in terms of their working processes. Therefore, either assessment and theoretical approach to creating and working cognitively diverse student teams could be used with equal success in a classroom environment.

Though the selection and organization of teams in this study was centered on similar academic majors, using FourSight or the AEM-Cube to create and arrange teams is not without precedent in classroom and industry settings. Therefore, using the assessments to form student teams or simply educating the already formed teams (as in the case of this study) are routes an instructor could take in giving place for cognitive diversity in the classroom.

This study utilized a three-part intervention to ensure that each student participant fully engaged with the desired treatment. This three-part intervention included (1) a visualization of student team cognitive diversity, (2) a theoretical framework to interpret diverse assets and contributions and understand potential interactions, and (3) a team charter to guide student teamwork in the context of the foregoing visualization and framework. This was relatively unique to this study and may have been one of the explanations for why student scores for knowledge integration capability and team member contribution were so high. Educators using either assessment could incorporate this tri-fold intervention as part or in place of some team forming activities. Students will then be able to visualize their diversity, understand that diversity in the context of teamwork, and put that diversity to work in a way that is productive and instills accountability by creating and adhering to a team charter or contract.

This intervention is also flexible in terms of time constraints. Each assessment takes about 10-15 minutes to complete; a range of 10-15 minutes to read and understand the results; and at least 10 minutes to create the team charter for a total minimum time of 30 minutes. Granted, one could spend a great deal more discussing individual team results and developing thorough team charters, depending on the nature of the course and the experience and/or interest level of the students. However, the point is clear: one does not need to invest an enormous amount of time to introduce cognitive diversity to the classroom.

Student teams work together often in short periods and neglecting to invest in positive and educational experiences around cognitive diversity because of temporal constraints can only hinder a student's preparation to work in the increasingly globalized marketplace. Thus, this three-part intervention demonstrates a flexible process by which students can be introduced and work with cognitive diversity ideas and frameworks in a relatively short amount of time. Based on the results of this study, no student team was hindered or burdened by implementing this intervention. Rather, and again, scores for team member contribution, psychological safety, and knowledge integration capability were each on the high end of their respective scales with no degree of team diversity outperforming another. The intervention may not be the reason for this success, but it certainly seems to be part of how diverse student teams can work more productively together.

5.3 Limitations and Barriers

It is important to note that the findings of this study deal with variables of *process,* not *outcome.* Knowledge integration capability is a variable that rates the *process* by which students assimilated assets among team members. Team contribution is another variable rating the involvement of team members *over time*. Therefore, a limitation of this study is that nothing can be said as to the quality of the product that was the result of their teamwork. Rather, the conclusions of this study speak directly to the processes these student teams were involved in while working together. Future research with these variables should then also include variables related to team outcomes.

This study took place during the COVID-19 pandemic. The Tech 120 course participated in a hyflex learning environment with some students participating only online, partially online, and others physically present on campus. Therefore, inferences to typical classroom experiences may not be appropriate. Due to the pandemic, students may have been more forgiving of student differences and shortcomings, which may explain the higher scores for the dependent and moderating variables.

In the case of the industry-based practices (such as the assessments and frameworks) used, a potential contextual barrier to this study is that it took place in the classroom rather than in industry. While applying methods based in organizational theories have been used with success in educational, classroom settings (Karlsson & Nowell, 2020; Curşeu et al., 2017; Srikanth et al., 2016; Bravo et al., 2019; Lamm et al., 2012; Oakley et al., 2004; van Broekhoven et al., 2020), there are obvious and potentially confounding differences between the classroom environment and the workplace. Conducting this study in an adult working environment—where AEM-Cube and FourSight are most often used—may have yielded different results.

Because of the way the treatment was designed, a limitation to this study is the potential possibility of having measured the “awareness” of diversity rather than actual cognitive diversity. Students were exposed to their results and discussed them openly, thus being aware of divergent approaches to problem-solving and other thinking patterns. Therefore, that awareness could have elicited various behaviors to compensate for, facilitate, or manage those differences. To what extent the awareness of diversity confounded this study is unknown and is therefore a limitation in how one is to understand and interpret the results.

The scope of this study did not include the analysis of variables of surface-level or functional diversity. Therefore, the level and influence of varying homogeneity among teams across surface-level, functional, and cognitive or deep-level diversity is unknown. Furthermore, the researcher did not delineate which preference the homogenous teams shared. In other words, in the context of FourSight and creative problem-solving preferences, the methods of this study did not help the researcher indicate whether a team was more homogenous in terms of ideating preference or in terms of implementing preference. However, the final results of this study may render such analysis unnecessary as there were no differences among varying levels of diversity.

5.4 Recommendations for Future Research

The current research investigation has yielded an interesting launchpad into further research opportunities that would greatly benefit the educational and industrial communities interested in cognitive diversity and teams. Therefore, the following are recommendations for future research:

This study was conducted using a posttest only design with dependent and moderating variable measures being administered at the end of a 4-week long design thinking project known as “Project Two”. However, there may be some merit to a pre/posttest research design as well. In the case of the TECH 120 course, Project Two is logically preceded by a much smaller project, Project One. The students in the class work together in their assigned teams for Projects One and

Two, thus a pretest could have been reasonably done if student changes (e.g., add/drop from the course, rearrangement of team members, etc.) were minimal or nonexistent. Therefore, future research could be done to test the validity of a pre/posttest research design and perhaps better measure the amount of growth (or decay) in knowledge integration capability, team member contribution, and psychological safety over time.

More research in deep-level diversity characteristics in the classroom, particularly in creative problem-solving preferences and strategic agility is needed to know the influence and impact that these variables have on varying educational processes and outcomes. No variables regarding teamwork *outcomes* were investigated in this study, therefore future research studies should investigate these variables in the context of both process and outcome variables.

The AEM-Cube assessment also creates team images with each team member's pin displayed in a single cube thus creating a visual of the spread of diversity. Further qualitative research could be done to investigate potential correlational patterns between team images and psychological safety and ratings of team conflict. Such a study would help provide more detail as to how the variance of individual strategic agility scores influence team satisfaction. A similar study could be done for using the FourSight team images and framework.

Certainly more research can and should be done in understanding the possible intersections of surface-level, functional, and deep-level diversity measures in student teams. How does one's combined demographics, past and relevant functional experience(s), and preferred approach to problem-solving impact their team experience? Is there a certain mix of these levels and types of diversity that is better than others for teamwork in short or long periods of time? Educators will continue to place students in teams for assumed benefits and understanding how various levels of diversity interact with those potential benefits will be key to ensuring a positive learning experience in the increasingly diverse classrooms around the world.

As stated earlier, the three-part treatment was somewhat unique considering the combination of the specific assessments used, the variables investigated, and the manner in which the students participated. Previous studies investigating diverse student teams have typically utilized only parts of this intervention. For example, Curşeu et al. (2018) used visualizations such as concept maps to assist students in mapping individual assets, but few guidance was given on how to understand why such knowledge differences exist and how effectively discern their use towards the end goal. Students often lack the experience to lead in contexts of diversity

(Oosthuizen et al., 2020; Scott-Young et al., 2019; Han et al., 2018) and are often in need of frameworks to help them interpret behaviors and team interactions, but such aid is either underutilized or missing in the process (Srikanth et al, 2016). Additionally, team charters have helped students to be successful in various team settings (Aaron et al., 2014; Byrd & Luthy, 2010), but because deep-level or cognitive differences negatively impact student collaboration over time (Harrison et al., 2002; Srikanth et al., 2016) team charters that take those differences into account are not widely used.

Therefore, future research into a three-part intervention where there is (1) a visualization of student team cognitive diversity, (2) a theoretical framework to interpret diverse assets and contributions and understand potential interactions, and (3) a team charter to guide student teamwork in the context of the foregoing visualization and framework is needed to better understand its efficacy in the student team experience. As the time periods in which students work together in teams fluctuates—a week to an entire semester or more—an understanding of the efficacy of this tri-fold intervention temporally would be of particular use to educators and researchers in the field.

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APPENDIX A. SURVEYS

Psychological Safety Survey

The survey is drawn from Edmondson's (1999) study on psychological safety and learning behavior in work teams. The Cronbach Alpha has been reported as α=0.82 for this survey. A 5-point Likert scale from "Strongly Disagree" to "Strongly Agree" was used with the survey items for this study. Survey items are as follows:

1. If you make a mistake on this team, it is often held against you.
2. Members of this team are able to bring up problems and tough issues.
3. People on this team sometimes reject others for being different.
4. It is safe to take a risk on this team.
5. It is difficult to ask other members of this team for help.
6. No one on this team would deliberately act in a way that undermines my efforts.
7. Working with members of this team, my unique skills and talents are valued and utilized.

Knowledge Integration Capability (KIC) Measure

The KIC is a self-reported 10-item survey using a seven-point scale ranging from positive through neutral to negative. Factor analysis of the items was conducted to confirm that "all items loaded into a single factor" (Gardner et al., 2012, p. 1007) indicating a reliable measure of the construct. The individual results can be averaged to create a single score per team. Gardner et al. (2012) did so while achieving high reliability, with a Cronbach's Alpha of α = 0.95.

Instructions: For each question below, please choose an answer to describe the communications that happened WITHIN YOUR TEAM.

Communications within our team were…

1. Relevant—Neutral—Irrelevant
2. Timely—Neutral—Delayed
3. Objective—Neutral—Biased
4. Clear—Neutral—Confused
5. Supportive—Neutral—Inconsiderate
6. Concise—Neutral—Digressive
7. Truthful—Neutral—Deceptive
8. Non-confrontational—Neutral—Confrontational
9. Right amount—Neutral—Too many/too few
10. Fostering teamwork—Neutral—Hampering teamwork

APPENDIX B. TEAM CHARTER

Team Charter

Below is the template for the Team Charter used in this study:

You have just completed an assessment that had as its aim to help you learn not only more about yourself but about others as well. There are no good or bad profiles—they are simply meant to help you understand more about yourself. Additionally, knowing the results and applying them to your team functions has shown to help teams of people be successful in tackling the challenges that face them. The purpose of this document, then, is to help you apply what you've learned from your individual assessment results by providing you with a clear understanding of your group strengths and weaknesses and give you an opportunity to plan on how to work with those weaknesses and strengths.

Instructions: You will need to complete this assignment with your team, but each of you will need to fill out this form on your own. **Be as specific as you can.**

1. First discuss each of your team member's profiles (assessment results). Remember, there are no good or bad profiles.

List Team Members (including yourself):	Describe their profiles:

2. Based on your profiles, list one key strength that each person brings to the team:

List Team Members (including yourself):	Key Strength:

3. Based on your profiles and your listed strengths (above), what knowledge or capabilities do you have available in your team that can help you on your upcoming project? (Write 3-4 complete sentences).

4. Every team has potential weaknesses as no team is perfect. List and describe at least 3 weaknesses you see resulting from the combination of profiles and then write how you will mitigate or overcome those weaknesses.

Weaknesses (at least three):

Mitigation plan:

APPENDIX C. TECH 120 LEARNING OUTCOMES

Learning Outcomes

Course learning outcomes for the TECH 120 course as written in Mentzer (2020, p. 1-2).

1. Write a narrowly focused problem statement addressing open-ended or ill-defined global challenges
    a. Describe how problems are nested in a complex system with technological, political, economic and cultural implications
    b. Identify opportunities to address global challenges
    c. Identify stakeholders in design contexts
    d. Identify measurable constraints and criteria

2. Apply ethnographic methods to understand technological problems.
    a. Gather, synthesize and use information to drive decision making processes
    b. Describe the Point of View of stakeholders
    c. Explain how ethnographic techniques provide empathy and how this relates to design
    d. Use observation and interviewing skills to understand a problem
    e. Evaluate a problem through measured constraints and criteria when applying ethnographic and quantitative methodologies
    f. Ask open-ended, penetrating questions to define a problem from the human perspective

3. Develop a search strategy, access technical data bases and evaluate results and source quality
    a. Determine the extent of information needed by defining the scope of research, key concepts and types of information.
    b. Access information using effective, well-designed search strategies in relevant sources
    c. Evaluate information and its sources critically, analyzing the assumptions and relevance of the contexts to the current problem
    d. Communicate, organize and synthesize information from several sources
    e. Access and use information ethically and legally

4. Create a technical report documenting results of the design process
    a. Identify essential elements of technical reports
    b. Present compelling information related to their problem and solution
    c. Use textual, visual and multimedia modalities to communicate
    d. Use proper citation methods

5. Manage design projects, develop project timelines and negotiate individual responsibilities and accountability in the team environment.
    a. Scope projects based on supplied time constraints
    b. Develop teams

c. Students will be able to provide feedback to team members regarding individual contributions to the group effort
d. Students will be able to communicate with the instructor about their performance and the performance of their teammates
e. Students will incorporate teammate feedback to improve their efforts

6. Apply strategies of ideation to develop novel and innovative solutions
   a. Provide examples of effective ideation processes resulting in potential alternative solutions
   b. Propose a solution that indicates comprehension of the problem and is sensitive to the content factors as well as the ethical, logical and cultural dimensions of the problem
   c. Systematically identify and evaluate solutions through the analysis of constraints and criteria

7. Prototype solutions for purposes of design, testing and communication
   a. Plan, implement and reflect on testing scenarios for their prototypes
   b. Give and receive constructive feedback in design critiques
   c. Present prototypes for the purpose of receiving feedback from peers