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Master's Dissertation 2021

# Improving Cognitive Consensus During Knowledge Sharing Process in Virtual Team Collaboration


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# SUMMARY OF MASTER'S DISSERTATION

| Student ID Number | 81934585 | Name | Edmilson Mansel Manuel Baptista |
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| Title: | | | |
| Improving Cognitive Consensus During Knowledge Sharing Process in Virtual Team Collaboration | | | |

Abstract:

The challenges posed by the COVID-19 pandemic forced many organizations to suddenly adapt to the virtual work environment at the start of the year 2020, and as a result, many businesses had to focus on understanding how to better support team members working virtually in order to boost their performance. Among the many studies on virtual teams, the notion of a team mental model has garnered a lot of attention and has been proven to have a direct and positive link with team performance. Previous research comparing the formation of team mental models in face-to-face and virtual work settings found that face-to-face team mental model development is by far superior. However, recent research has shown that just sharing information cannot promote the proper development of a team mental model in virtual work. Our research emphasizes the concept of cognitive consensus, defined as the ability of people to interpret knowledge shared in a similar way, as a mediator between knowledge-sharing activities and team mental models. Few studies have focused on proposing a step-by-step process that can help virtual teams improve cognitive consensus during knowledge-sharing activities. The study's goal is to propose a systematic process that can help virtual teams improve cognitive consensus during the knowledge-sharing process. We use a triangular fuzzy conversion scale to assess team members' preferences for the knowledge shared in terms of importance, and cognitive consensus level calculation was utilized to measure team members' level of agreement on the same knowledge shared. Our findings show that when virtual teams take the time to communicate their comprehension of task information as well as their preferences for what knowledge appears to be crucial for team performance, the amount of cognitive consensus and shared understanding improves. As a consequence, members of virtual teams will have a better opportunity of developing a stronger team mental model.

Key Words (5 words)

Virtual Teams, Team Mental Model, Knowledge Sharing, Cognitive Consensus, Fuzzy Cognitive Mapping.

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# 1. INTRODUCTION

On 11th March 2020 the covid-19 was declared a pandemic and countries around the world needed to start taking action in order to prevent and lower the rate of the covid-19 infection (Paula Persson, 2020). One of the measures taken by many governments to help reduce the spread of the covid-19 pandemic was to recommend businesses and employers to allow their employees to start working from their homes. This sudden shift in the working culture in many companies due to the pandemic gave rise to the trend of teleworking.

The practice of working from home as known as teleworking is not a new concept. Since the rise of the internet and the release of new and better Information and Communication Technologies (ICTs) software and tools, the working culture surrounding many companies have evolved, allowing people to work and collaborate from the comfort of their homes, or in locations other than their offices on a daily basis. Going a step further, the evolution of ICTs allowed people from different geographical locations and different time zones to collaborate, coordinate, and communicate in order to achieve the same task (Yager,2000). However, the sudden need for employee to start working virtually from their homes or outside a common place like their office brought many challenges and revealed many difficulties concerning the abilities of teams to collaborate virtually.

Teams are a fundamental part of any organization and more than ever they have been playing a major role in organizational productivity since the pandemic has started and with the recent challenges faced by the teams in many organizations comes the need for understanding how we can make the process of collaboration in virtual teams more satisfying, efficient and productive.

## 1.1. Background

Organizations create virtual teams where team members geographically distributed around a country, and sometimes around the world, work together towards the same goal to accomplish important tasks (Lipnack & Stamps, 2000). Virtual team are defined as groups of geographically and/or organizationally distributed participants who collaborate towards a shared goal using a combination of information and communication technologies (ICT) to accomplish a task (Townsend et al., 1998; Lipnack & Stamps, 2000; Majchrzak et al., 2000; Kirkman et al., 2004; Handy,1995)

Together they work to develop innovative products, strategize and crucial organizational problems (Mohrman, Klein, & Finegold, 2003). Some virtual teams collaborate, communicate and coordinate tasks through the use of ICTs such as email, instant messaging, teleconferencing, and videoconferencing (Rosen, B., Furst, S., & Blackburn, R. (2006)). While working, virtual teams are confronted with different challenges concerning the ability to reach a common understanding of the overall task that needs to be solved (Townsend et al., 1998).

Previous research has indicated that the reason for such difficulty in virtual teams is because virtual work offers an artificial process of social interaction, which as result demotivates team members to seek for knowledge and develop common understanding about the same knowledge shared (Kock's, 2004). Hence, team members in virtual teams spend most of their time trying to solve task-related cognitive conflict (Chiravuri, A., Nazareth, D., & Ramamurthy, K. (2011)).

Past research has shown the positive relationship between team mental model and team performance, and has concluded that the development of team mental model in virtual teams' collaboration is inferior compared to face-to-face team collaboration ((Andres, H. P. (2011)). Since individuals working in virtual teams have difficulties in reaching common understanding and consensus about the knowledge and information shared, it negatively impacts the development of team mental models which affects their team performance. Hence, studies emphasizing how virtual team members can develop shared meaning and cognitive consensus during team collaboration is very essential.

## 1.2. Problem Statement

To participate in successful negotiations and to avoid or rapidly recover from communication failures, group work needs shared meaning. To make sense of one other's activities, team members must create a shared meaning, context, and common language. Creating shared meaning usually happens over time and via face-to-face interaction (Chudoba et al., 2005). As a result, because access to each other is only mediated through the traces left in technology, geographically distant individuals have a considerably more difficult challenge when establishing shared meaning. However, there is a risk that individuals may misinterpret the knowledge shared by other teams members. The absence of regular co-located encounters for social or work-related activities hinders the formation of a common meaning context and raises the likelihood of communication breakdowns. Creating a shared meaning context is the act of establishing common ground; failure to develop and maintain such a context can result in significant breakdowns in collaboration (Cramton, 2001). Another important element of cooperation is knowledge sharing, which is strongly connected to the process of constructing a team mental model or creating a shared meaning. Knowledge is transferred and vice versa during the ‘process of consensus building' (Malhotra & Majchrzak, 2004). However, one critical issue is how to create cognitive consensus of information shared during virtual team cooperation in a systematic manner. There has been little research into understanding and researching how virtual teams may establish cognitive consensus in a systematic manner (Harmon, J., & Rohrbaugh, J. (1990), Mohammed, S. (2001)).

## 1.3. Research Aim

The primary goal of this research, conducted in the midst of a pandemic and current virtual work demands, is to identify the factors influencing virtual teams' cognitive consensus during knowledge exchange and to propose a process for improving the level of cognitive consensus between team members during the knowledge exchange process. By gathering data from questionnaires and doing calculations to determine team members' level of cognitive consensus of information provided during the task process, qualitative and quantitative techniques were utilized to verify and validate the suggested methodology.

# 2. LITERATURE REVIEW

## 2.1. Virtual Teams

A virtual team is described as a collection of individuals or stakeholders that collaborate on a similar project from different places and perhaps different time zones and utilize information and communication technologies (ICTs) extensively to co-create. One of the primary features is virtuality, which involves physical and temporal distance between members as well as a common objective (Ebrahim et al., 2009).

Virtual teams have been considered to transform the business working culture by displacing conventional teams in different geographical locations, and allowing companies to participate in more sophisticated and dynamic initiatives (Oakley, 1998). They are being characterized as a new way of working together to achieve a project or objective and they can be made up of individuals across disciplines, roles, cultures, and companies. Individuals working virtually can combine their unique talents in order to temporarily work together and achieve a goal (Cohen and Mankin, 1999). Because many members are geographically dispersed and occupy various functional responsibilities in organizations while working, virtual teams tend to be more dynamic than conventional teams. As a result, virtual team members must become more proficient at working with people from other cultures and backgrounds than their own (Townsend et al., 1998).

***Advantages***

Previous studies have considered virtual teams to be connected to considerable savings for organizations as a result of reduced travel charges, meeting hours, duplication costs, and other expenses (Robbins & Judge, 2007). Second, virtual teams make businesses more adaptable, helping them to deal with the constraints brought on by expanding corporate globalization and rivalry, changing organizational structures, and rising consumer demand for quick and efficient service (Avolio, Kahai, & Dundis & Benson, 2003). Because virtual teams are a cost-effective business strategy that helps businesses enhance their competitiveness, organizations are expected to continue to utilize or embrace virtual teams in the future.

***Challenges***

Previous researchers have pointed out a variety of problems exist in the virtual environment that might jeopardize the efficacy of virtual teams. Coordination of team tasks, establishing successful working relationships with unseen and possibly (at first) unknown teammates, overcoming communication and cultural hurdles, and learning new technology are among the challenges (Gibson & Manuel, 2003).

Virtual team members may face a variety of logistical challenges when coordinating work with remote team members. Such issues can arise when team members operate in various time zones, when local communication infrastructures fail, and/or when local work needs fluctuate. ((Montoya-Weiss, Massey, & Song, 2001)

Schedule problems, missed meetings, and unreturned emails and phone calls discouraged some team members. These issues can irritate team members, resulting in reduced team commitment and performance. Team members may have attributed a colleague's lack of engagement to a lack of commitment to their local job obligations. Some team members questioned the team's commitment to virtual initiatives and worried about possible "free riding" by team members. The researchers found that some team members were more concerned with their virtual team objectives than their real-life colleagues' needs. (Furst et al. (2004))

Miscommunications between and among virtual team members are all too common. For example, emotional components of communication such as hope, rage, humor, sarcasm, or irritation may be missed or misconstrued. To compensate for the lack of nonverbal clues, team members may be tempted to provide contextual information that conveys such meanings in unconventional ways. E-mail users may add emotional meaning to communications by using symbols such as the ubiquitous emoticons or by changing the typeface to signify emphasis or rage. However, these symbols express only elementary sentiments at best and do not allow virtual team members to transmit and/or identify the subtle subtleties in meaning while interacting online. (Poe, 2001)

Virtual teams can face problems of building team identity and building relationships in the absence of face-to-face communication. Virtual team members may reinforce their erroneous preconceptions based on any of their personal characteristics while interacting without the advantage of visible or audible signals. Problems with creating team identity, for example, are likely to be amplified due to team members' diversity in terms of experiences, talents, beliefs, functions, places, and cultures. (Duarte & Snyder, 2001)

***Virtual team vs face-to-face team***

While many organizations have been migrating from traditional teams to virtual teams, there are differences that come with working virtually compared to face-to-face in terms of structures, form of communication and the way they cooperate. Virtual structures are decentralized, flat, and informal, with companies often joining forces to adapt to new procedures and other advances more rapidly. (Yager,2000). In contrast, face-to-face teams' structure is characterized by being a centralized, hierarchical organization where each company performs all of its work independently. (Allcorn,1997).

Another difference is that in virtual teams the flow of information happens in an asynchronous manner, and by allowing individuals from different cultures and backgrounds to work in the same project or task it creates a heterogeneous working culture amongst virtual team members (Yager, 2000). On the other hand, traditional teams are able to maintain a homogeneous working culture among their peers since the flow of information happens in a synchronous way. (Allcorn, 1997)

### *Collaboration in Virtual Teams*

Schrahe, 1990 defined collaboration as a deliberate activity motivated by a desire or necessity to solve a problem, create, or discover something new. Also, Aram and Morgan 1976, defined collaboration as the existence of mutual influence among members that enables open and direct communication, resulting in conflict resolution, and support for innovation and experimentation. Collaboration is a much deeper process than communication or simple teamwork. It entails creating value in ways that conventional communication or collaboration cannot. Collaboration is limited by a variety of variables such as expertise, time, money, and competition, among others. In the end, it is not just about being able to communicate with each other it is also about creating value.

For collaboration to exist 3 main factors need to be present, and they are: trust, depth of relationship and shared understanding.

Trust is a key alignment factor for geographically dispersed workers who spend a significant amount of time working alone in places remote from other team members and direct supervisors. Individual members would not be prepared to accept the chance that another team member would act in their own self-interest rather than the teams' interests if there was no trust (Peters, L. M., & Manz, C. C. (2007)). The same way, depth of relationship is another important factor for virtual teams' collaboration because it helps in understanding the value of team member connections and establishing alternate methods of developing them early in the project is essential to ensure trust, shared understanding, and a productive team atmosphere (Peters, L. M., & Manz, C. C. (2007)). Finally, shared understanding entails accepting the team's strategic direction, including an awareness of the skills each member brings and how they may interact to achieve the overall goals (Liedtka, 1996). Members are driven to cooperate and participate in order to make the virtual team connection work by motivating them to care about the overall process rather than just their individual contribution (Duarte and Snyder,2001).

## 2.2. Knowledge Sharing

All teams, including virtual teams, must establish methods for sharing information, experiences, and insights that are important to completing their goals. The ability of team members to share such information and knowledge helps in the development of new products, services, processes, ideas, and policies.

Knowledge has been defined as a justified belief that increases an entity's capacity for taking effective action…" (Alavi and Leidner (2010)). The development of knowledge starts by taking place at an individual level by members creating knowledge independently, as well as at a social level through members' interaction and collaboration. (Nonaka 1994). However, the process of converting individual knowledge into group knowledge comes with many complex challenges, and if those challenges are ignored, it can increase the employee's reluctance to share knowledge virtually which can affect team collaboration and result in team members not being able to achieve their task goals. (Van den Bosch et al., 1999).

***Classification***

Previous literature has classified knowledge into two types, explicit knowledge and tacit knowledge. Knowledge that can be collected and described in words and figures and disseminated in the form of data via courses or books for self-reading, scientific formulas, specifications, manuals, and the like is characterized as explicit knowledge. This type of information may easily be formalized and disseminated across people (Seubert et al., 2001).

Tacit knowledge is information that is exclusively known by one person and is difficult to transmit to the rest of the organization. Tacit knowledge, according to Nonaka and Konno (2000), is firmly embedded in an individual's actions and experiences, as well as the beliefs, values, and emotions he or she accepts. The first is the technical dimension, which includes the type of informal personal talents or trades that are frequently referred to as knowhow. The second is the cognitive component, which includes deeply established beliefs, concepts, values, schemata, and mental models that we frequently take for granted.

This cognitive component of tacit knowledge influences the way we view the world, despite its difficulty in articulating it. Because tacit knowledge is ingrained in corporate processes and the people who make up an organization, it is difficult to collect. It's incredibly difficult to assess and manage since it's very customized, context-sensitive, and informal. It comprises know-how, intuition, and informal communications, all of which contribute to the company's culture (Nonaka and Konno, 2000). Jennex (2007), on the other hand, t what is implicit to one individual may be obvious to another (Jennex (2007)). This feature has prompted many academics to realize the necessity of converting tacit information to explicit knowledge and to do study on ways to provide tacit knowledge to a larger range of organization members. As a result, many businesses have begun to focus more on knowledge management in order to gain a competitive advantage (Jennex, 2007).

Table 1. Difference between explicit and tacit knowledge (source: Goffin et al., 2010)

| | Explicit Knowledge | Tacit Knowledge |
|---|---|---|
| Nature | -Easy to identify<br>-Easy to share<br>-It is inherently incomplete, lacking context, and needs interpretation. | -Hard to identify, resides within persons mind<br>-Hard to articulate<br>-Difficult to share<br>-Shared indirectly and sometimes unconsciously |
| Examples | -Task information<br>-Know-what<br>-Policies<br>-Rules and Procedures | -Mental models<br>-Intuition, Ideas, opinion, insights<br>-Know-how<br>-Beliefs<br>-Interpretation |
| Representation and Sharing Mechanism | -Documentation<br>-Codification<br>-Group repositories | -Practice<br>-Drawing mental model and cognitive maps<br>-Story telling and metaphor<br>-Personal reflection<br>-Group brainstorming |

***Characteristics***

Information sharing entails disseminating current knowledge among team members as well as bringing new knowledge into the team from outside sources. These knowledge in virtual teams are shared by using e-mail, phone, instant messaging, text messaging, electronic bulletin boards and discussion forums, adapting groupware for document distribution, and the creation of dedicated team Web pages, which are often equipped with sophisticated search capabilities. (Rosen, B., First, S., and Blackburn, R. (2007)). However, the most essential fundamental about virtual teams during knowledge sharing activities is not the use of Information and communication Technology, but the desire and willingness of members to engage into the knowledge sharing process. This is because virtual teams need to take upon themselves many responsibilities varying from inquiry response, brainstorming new ideas and concepts, decision making, sharing documents, team briefings, team strategy development and so on. Thus, the success of virtual teams most of the time lies on the ability and motivation for team members to share knowledge with each other and reach common understanding.

### *Advantages*

Previous research done on knowledge sharing in virtual teams have found positive results when team members engaged in sharing knowledge. For example, (Rosen, B., First, S., and Blackburn, R. (2007) found that knowledge sharing improves virtual team performance by encouraging more efficient use of team resources and decreasing implementation mistakes. Virtual teams that excel in knowledge sharing may expect greater team cohesiveness, contentment, and motivation. Alsharo, M., Gregg, D., & Ramirez, R. (2017) argues that by guaranteeing that all parts of an information jigsaw are available for task performance and proper decision making, knowledge sharing by member experts will allow optimal team results. This enables the team, regardless of location, to complete its job requirements and contribute to the goals of a company.

### *Challenges*

Besides the several benefits that come with sharing knowledge in a team, virtual teams especially face many difficulties to share knowledge in an efficient and effective manner. Those difficulties are much more prominent in virtual teams because of the characteristics offered by the virtual environment. Those characteristics sometimes contribute as a barrier for knowledge sharing in virtual teams. Barriers such as lack of trust among team members, time constraints, deadlines, type of technology used, the ability of team leaders to encourage knowledge sharing in groups, cultural differences, time differences, are just some of the many barriers virtual teams face during the knowledge sharing process. (Fussell et al., 1998; Jarvenpaa and Leidner, 1998; Alavi and Tiwana, 2002; Powell et al., 2004). Furthermore, virtual teams take longer to establish consensus and work successfully since they don't have the benefit of face-to-face engagement (Holton, 2001; Potter and Balthazard, 2002; Kirkman et al., 2004; DeOrtentiis et al., 014; Pangil and Chan, 2014). These challenges, if not addressed and managed appropriately, can affect the performance of virtual teams (Piccoli et al., 2004).

### *Overcoming Barriers during Virtual Knowledge Sharing*

Previous studies have identified good practices that can help virtual teams overcome barriers. Recommendations vary from team leader building a safe team culture around virtual team to improve trust among team members and increase collaboration, schedule face-to-face meetings at least once a year, schedule regular conference calls to enforce knowledge sharing habits, create a repository where team member can share and retrieve information, provide training to team members on how to use and adapt to the new collaboration technologies, team leader should ensure that information is shared in a timely manner, educate team members about possible cultural differences and how to overcome it, and many others.( (Rosen, B., First, S., and Blackburn, R. (2007)

## 2.3. Team Mental Model

Through the use of information and communication technology, cooperation may be done on a virtual level in changing corporate settings owing to technological advancements (ICT). Virtual teams have distinct problems than face-to-face teams, such as distant comprehension of the entire job at hand. On a face-to-face level, previous research has demonstrated that Shared Mental Models (SMM) are critical for a team's performance. Previous literature on the topic of mental models have described it as a way for organizations and individuals to construct and exchange meaning, allowing for a shared understanding and knowledge development (Hill and Levenhagen, 1995; Flood, 1999; Pruzan, 2001). Shared mental models, in which employees within an organization have a shared understanding, offer frameworks of value and belief systems that serve as the foundation for analyzing any new ideas, concepts, policies, or cultural trends under consideration by a team (Caldwell et al., 2002; Swaab et al., 2002).

***Definition***

Individual cognitive displays pertaining to one's particular structures as a foundation for interaction are characterized as Mental Models (Rouse, 1986). It aids in the explanation of an individual's decision-making process, and exposes the demands of individuals to perform in certain scenarios. It can be seen as an essential roadmap to provide understanding, explanation and predictability of individual actions, preferences and behavior during decision making process and team work (Fung, 2014). When a team mental model is developed it means that there is a shared understanding among members of a team about particular aspects of professional issues such as task, performance, and interaction (Cannon, 2001).

Based on Cannon et al., 1993, team mental model refers to shared knowledge about team members' characteristics and team interaction patterns that enable team members to adapt and coordinate with other team members in completing a task.

Shared mental models are classified into two types: task-related mental model and member related mental model. Member related mental model refers to common knowledge about team roles, responsibilities, interdependencies and interaction pattern among team members and task-related mental model refers to the shared knowledge regarding team members knowledge, skills, attitudes and preferences.

Table 2. Classification of shared mental model

| Shared Mental Models | | | |
|---|---|---|---|
| **Task-SMM** | | **Team- SMM** | |
| **Task Mental Model** | **Equipment Mental Model** | **Team Interaction Mental Model** | **Team Mental Model** |
| -Task procedure<br>-Likely contingencies<br>-Likely scenarios<br>-Task strategies<br>-Environment Constraints<br>-Task Component<br>-Relationship | -Equipment Functioning<br>-Operating Procedures<br>-System Limitation<br>-Likely Failures | -Roles/Responsibilities<br>-Information sources<br>-Interaction Patterns<br>-Communication Channels<br>-Role Interdependencies<br>-Information Flow | -Teammates* Knowledge<br>-Teammates*Skills<br>-Teammates* Attitudes<br>-Teammates* Preferences<br>-Teammates* Tendencies |

***Characteristics:***

While working virtually, it is important that individuals realize the different mental model held by members in the same group at the beginning stage of collaboration. (Klimecki and Lassleben, 1999), and this will help team members to address new information coming into the group in a meaningful way. When a person observes a difference in mental models, he/she rationalizes it and, when accepted, this new stimulus is internalized and the mental model is modified to reflect new information and grow into knowledge. At this level the person communicates his/her understanding, which leads to the development of new knowledge, through the process of team communication. Some discrepancies can be streamlined and incorporated into the collective mind model as a result of dialogue. This adapted mental team model now serves as the basis for mutual reference and the production of new knowledge. (Davison, 2005)

What this means is that once team mental models are in place, they get stronger and more likely to become self-referential, allowing them to become stronger. Team members' actions become more predictable and eventually reduces flexibility and adjustment to new ideas (Hill and Levenhagen, 1995). If the common frameworks themselves become an issue, then collaborative learning and successful knowledge growth, not just inside groups, but throughout the company as whole, are shaped by subsequent, reduced and flexible levels.

### *Advantages*

It has been argued that shared mental models are of great value to a group of individuals, as they both provide a predictability aspect that promotes communication, thus facilitation coordination of work, cooperation (Wetzel and Buch, 2000; Dickson et al., 2001), and the connection between communities of work and individuals working together towards the same goal (Doyle Conner et al., 1994; Dixon, 2000).

In addition, common understandings facilitate learning and serve as a foundation for the creation of all new information. As a result, shared mental models will be critical because they offer the framework that will influence the scope, kind, and acceptance of information that may be assimilated and understood by the team, functioning as delimiters of new knowledge within and across teams. (Davison, 2005).

majority of researches on shared mental model have given emphasis on the importance of having mental model convergence or overlapping among individual's mental models. (Dechurch and Mesmer-Magnus, 2010a). This convergence of individual mental model will enable team members to be on a common understanding, hence enhancing performance and team effectiveness. With common knowledge, the team is more likely to make fewer mistakes and establish comparable methods of thinking when confronted with a circumstance such as a problem meeting a project deadline or a struggle completing the project within the budgetary constraints. (Fung, 2014)

### *Challenges*

Previous studies comparing the development of team mental model in virtual environment with face-to-face environment have concluded that team mental model development in virtual team is very limited compared to that of face-to-face team. (Andres, 2011) Because of the lack of verbal and emotional cues in the virtual work environment team members have less motivation to engage in knowledge exchange which is essential to the development of team mental models. Other challenges like technical issues from software and hardware used to assist collaboration, time difference and distance contribute to increasing the difficulties for team members to reach a common understanding.

### *Knowledge sharing and team mental model relationship*

Knowledge sharing has been defined as the process of passing explicit information and an individual's mental models from one person to the next, or from one social system to the next (Jonassen,1994). Knowledge sharing behaviors have been considered to aid in the improvement of working skills and the development of team knowledge (Wang et al., 2006). It entails complex social interactions such as event perception, intents, interpretations, observations, and reflection on one's own thoughts and actions (Kuo and Young (2008)).

The term "Team Mental Model" has been used extensively in the study of common cognitive structure within a social system. (Cannon-Bowers et al, 1993), and has been defined as a cognitive architecture that enables effective team coordination and collaboration, emphasizing the importance of similarity in an individual's mental model within the same team and its positive impact on team success (Gross, N., & Kluge, A. (2012)). This shared mental model allows team members to anticipate other people's needs and actions, synchronize their work, and support effective information retrieval and sharing (2010 (Dechurch and Mesmer-Magnus))

Previous research in the Team Mental Model literature has identified knowledge sharing as a critical factor in the development of common cognitive architectures of teams (Gross, N., & Kluge, A. (2012)). Knowledge sharing behavior within teams is assumed to aid team members in interpreting cues in a similar manner, making compatible decisions, and taking appropriate actions (Klimoski & Mohammed, 1994; Johnson & Lee, 2008).

As a result, there is widespread agreement within the cognitive behavioral structure research community that knowledge sharing behavior within teams has a very strong relationship to the development of team mental models.

***Team mental model and team performance relationship***

The team mental model, also known as the content and knowledge structure shared by team members while working on a team task, is a very complex cognitive concept (Yang et.,al 2008). It is primarily based on the individual mental model, which represents the individual's actions, perceptions, expectations, and understanding of the task and the environment (Rouse and Morris, 1986). The team mental model, on the other hand, is a team-level concept that develops when members of the same team share a common mission and when there is a need for cooperation and coordination among team members in order to complete a task (Xiang et.,al 2003).

Previous research has shown that the success of team members working on the same project is determined by the similarity or convergence of their individual mental models into a team mental model, as well as the accuracy of the team mental model to the task characteristics (Yang et al., 2008).

The extent to which a team is able to meet its output goals (e.g., quality, functionality, and reliability of outputs), the expectations of its members, or its cost and time objectives is defined as team performance (Ancona & Caldwell, 1992). According to researchers, the development of team mental models within a team has a significant and positive impact on team performance (Xiang, C., Yang, Z., & Zhang, L. (2016)).

There are two types of team mental models: member-related mental models and task-related mental models (Yang et al2008). The similarity of team' tasks and member’s mental models, in particular, will improve team performance and effectiveness (Yang et al., 2008.). Other studies have linked team mental model development to improved decision quality by reducing conflicts in teams (Kellermanns et al., 2008) and increasing common understanding and overall task performance (Johnson and Lee 2008).

Based on above literature reviews, we have concluded that the team mental model has a very strong and positive link with overall team performance and effectiveness.

***Shared knowledge, team mental model and team performance relationship***

According to the research made on the relationship between these 3 importance subjects in supporting team collaboration the following relationship is illustrated.

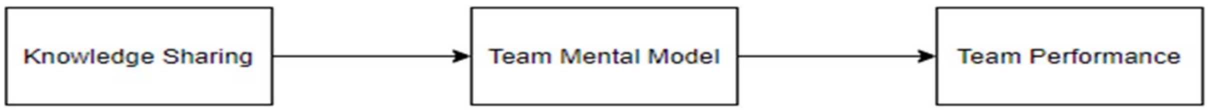


Fig.1 Relationship between knowledge sharing, team mental model and team performance

The relationships mentioned above have proven to be extremely useful for face-to-face teamwork. Recent studies that attempted to assess the applicability of this relationship on virtual teams discovered that the link between knowledge sharing, team mental models, and team performance is not very strong. According to research comparing the development of team mental models through knowledge sharing in virtual teams and face-to-face teams, the development of team mental models in virtual teams is very limited when compared to those in face-to-face teams. H. P. Andrés (2011) As a result, teams that collaborate virtually achieve lower work performance than team members who collaborate face-to-face.

There are numerous causes that researchers have identified to explain why this relationship is inferior for virtual teams. (Andres, H. P. (2011) discovered that the technology-mediated collaboration mode exhibited longer lags between information exchanges, fewer information seeking attempts, more incoherent exchanges, a greater need to repair misunderstandings, and decreased team-wide participation, all of which limited the extent of shared understanding among all team members. Apparently, a lack of co-presence/proximity effects (i.e., social impacts of strength and immediacy) might reduce team member involvement and team members' capacity to appropriately respond to verbal and nonverbal signals used to facilitate confirmation of comprehension and consensus. Furthermore, (Badke-Schaub, P., Neumann, A., Lauche, K., & Mohammed, S. (2007) discovered that sharing knowledge in a virtual team does not always result in the development of a team mental model due to a lack of consensus about task process and task information. Other researchers have linked the problem to the artificial process of social interaction offered by virtual environment during virtual team collaboration, which reduces team members' incentive to engage in the behavior of exchanging knowledge and reaching a shared interpretation. (Kock, 2004.)

Based on the conclusions made from those previous researches the common issue is related to the knowledge sharing process. In a virtual team the process of sharing knowledge does not seem to be as effective as in face-to-face teams. The social interaction process in a virtual environment does not allow virtual teams to reach a common understanding about the task-related and members-related knowledge shared needed to develop a strong team mental model. Reaching a common understanding on how team members interpret information and knowledge is one of the essential fundamentals of team mental models.
This divergence in the interpretation of information and knowledge in virtual teams may happen due

to the several factors associated with the characteristics of virtual teams. Virtual teams normally tend to include team members from various functional backgrounds, departments, and organizational levels. As a result, individuals frequently join the group environment with varying viewpoints and interpretations of knowledge shared. Members are confronted with their colleagues' opposing viewpoints through contact and debate and must strive to reconcile divergent assumptions underlying the issues. (Mohammed, S., & Dumville, B. C. (2001))

This variation of point of views and interpretation from virtual team members is part of their belief structure. Knowledge shared in virtual teams is considered as part of knowledge structure, which is concerned with the descriptive states of nature that one knows or thinks to be true, but belief structure is concerned with the desired states of nature that one prefers or expects (Mohammed et al., 2000). In other words when team members working virtually engage in the process of sharing information and exchanging knowledge, their interpretations of that knowledge and information may vary based on their belief structure, or rather based on the predominant expectations and preferences of the task they hold in their minds. Therefore, it is important that in virtual teams, members have the capacity to share their expectations and hold their interpretations about the knowledge shared in a similar way in order to develop a common mental model.

Belief structures are often treated separately from knowledge structures in many literatures (Mohammed, S., & Dumville, B. C. (2001)). In order for us to understand how team members perceive and interpret the same information which is essential for the team's task, belief structures should be implemented or combined with knowledge structures. The one that deals with understanding individual belief structures is called Cognitive Consensus (Mohammed, S., & Dumville, B. C. (2001)).

***Team mental model and cognitive consensus***

Cognitive consensus refers to similarity among group members regarding how key issues are defined and conceptualized (Mohammed and Ringseis, in press). Rather than focusing on raw information content, cognitive consensus deals with the interpretation of the information, how it is viewed by the group, and the opinions that are held about it. Therefore, it is likely that knowledge structures will occur more readily than the development of cognitive consensus, which makes studying group cognitive consensus a much more complex matter, since for knowledge sharing accuracy and similarity are the most important variables, whereas with cognitive consensus it is much more problematic since it is subjective in nature. (Mohammed, S., & Dumville, B. C. (2001)).

### 3.4. Problem Discussion

Due to the complex and subjective nature of cognitive consensus many research has focused only on how groups negotiate to reach consensus on decisions, very less is known about how group members negotiate to reach cognitive consensus on the interpretations of issues (e.g., Brehmer, 1976; Bettenhausen, 1991). Researchers believe that teams that have more cognitive consensus are likely to attend to, interpret, and communicate about issues more similarly than individuals who have less cognitive consensus (Mohammed and Ringseis, in press).

Therefore, the study of cognitive consensus during the knowledge sharing process in a virtual team will be our main focus. We believe that by understanding how team members working virtual reach cognitive consensus about how they negotiate the interpretation of key knowledge and information related to the task, virtual team members will be able to develop a much better team mental model. Thus, we propose that the cognitive consensus process will act as an intermediary assistant between the knowledge sharing process and team mental model development.

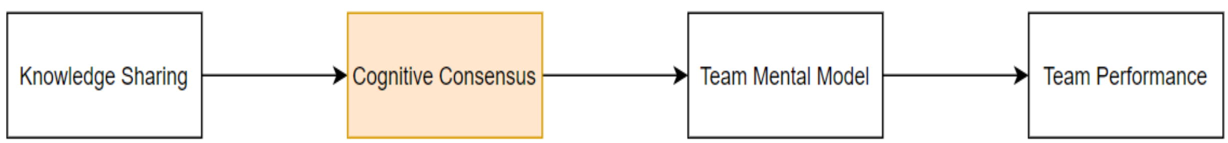


Fig 2. Improved model

# 3. RESEARCH PROPOSAL

## 3.1. Overview

The current research proposal was done based on the previous works which focused on the relationship between knowledge sharing, team mental model and team performance. This proposal takes into account the influence of cognitive consensus process in virtual team collaboration during the knowledge sharing which is a necessary input to develop team mental model. Previous researchers have already pointed out that sharing knowledge in a virtual team is not enough to develop a solid team mental model, which as result improves team performance.

As mentioned in the problem discussion section, in this study we will be focused on studying how the cognitive consensus process happens in a virtual team and the factors influencing convergence of members' cognitive interpretation about knowledge shared during the collaboration process. Ultimately, with this study we hope to contribute to the literature of virtual team cognitive consensus during knowledge sharing by proposing a cognitive consensus process to support the development of virtual team mental models.

Previous studies done in the area of cognitive consensus in teams have focused on cognitive techniques to help representation and elicitation of team cognition such as Delphi technique and repertory grid technique (Chiravuri, A., Nazareth, D., & Ramamurthy, K. (2011), others have focused on the measurement of team cognition by using tool such as concept maps, (Debra and Tristan, 2004), measurement of team cognitive disagreement by using cognitive fuzzy mapping (Kosko, B. (1986)), and the basic concepts related to cognitive consensus(Mohammed, S. (2001)). However, there are few researchers focusing on a systematic process to help virtual team members achieve cognitive consensus during knowledge sharing activities (Harmon, J., & Rohrbaugh, J. (1990), Mohammed, S. (2001)).

Our research effort will be to bridge that gap and try to propose a systematic process that can help virtual teams reach cognitive consensus during knowledge sharing by studying previous research on the topics of factors influencing cognitive consensus in both virtual and face-to-face team as well as by conduction several experiments to understand how virtual teams share knowledge during collaboration and what mechanisms can be used to facilitate convergence of cognitive interpretation.

## 3.2. Factors influencing cognitive consensus in virtual teams

In order to create a systematic cognitive consensus process, many previous experiments were conducted to understand how the process of knowledge sharing among virtual team members happens and what kind of factors are present during team interaction that facilitate the development of common understanding of their knowledge.

Those experiments paved the ground and gave us the foundation to design our process for knowledge sharing consensus in virtual teams, and many insights on how to make the process better for the virtual team members. Below are some of the insights gotten from those experiments.

***Experiment #1***

*Objective of experiment:* to understand the difficulties virtual teams face in reaching cognitive consensus and agreement while sharing ideas /opinion during team collaboration while solving a task.

*Sample and equipment:* 4 people were invited to participate in the virtual teamwork experiment. The participants were located in different places throughout the whole experiment. All participants were university students and with an age range above 20 years old and with academic background above undergraduate degree. The team collaborated together virtually by using two main collaboration software: Miro and Zoom. Miro is an online collaborative whiteboarding platform that enables distributed teams to work effectively together, from brainstorming with digital sticky notes to planning and managing agile workflows. Zoom is a software application that provides video telephony and online chat services through a cloud-based peer-to-peer software platform and is used for teleconferencing, telecommuting, distance education, and social relations.

*Task objective:* team members worked together to solve a map puzzle. They needed to share their ideas and opinions that could help their team solve the puzzle in a very efficient way.

*Scenario:* a common virtual board was created by using the Miro software, which enables team members to collaborate real time on the same task. Every team member could access the same board from their laptops. On this board team members would verbally share their ideas and opinions with each other. Zoom software was used as a communication tool to help team members discuss their ideas and negotiate. Team members used videoconference to communicate with each other.

*Steps:*

1. Before the experiment began, each team member received a portion of information that would help them solve the map puzzle. That information was related to each other but were not the same. This fact by itself created the right situation for team members to share information and community with each other during the experiment.

2. Once team members were connected by Miro and Zoom software the experiment began. First, they were introduced to the overall experiment and read the instructions which were available on the Miro board. The instructions asked team members to share the information that each one received separately by writing it on the common board. Information such as "There is a John's shop in the northwest of the shop with the cherry tree" "The bakery is in the South of the butchery", were shared in the common board and every member could read and interpret the information.
3. After sharing that information, team members were asked to think about the best ways to solve the map puzzle and verbally share their ideas and opinions with each other through discussion. After sharing and discussing their opinions and ideas, team members would agree on a strategy choosing which ideas would help them in solving the puzzle.

4. After agreeing on the strategy team members began to work on solving the puzzle till the task was completed.

*Results:* overall team members took about 42 minutes to solve the puzzle.

*Insights from this experiment:*

1. Having a common space to share their information was very helpful for their task coordination, however it was not enough to develop cognitive consensus about that information shared in the common board.
2. While reading the shared information on the common board, team members had different interpretations about the same information, as well as different expectations on how to solve the puzzle.
3. Sharing their ideas and opinion verbally on how to solve the puzzle was not enough to develop agreement and consensus on what ideas would be part of their team strategy. Team members could not agree with others point of view in the beginning which made collaboration difficult, resulting on some members starting to solve the map by their own based on their understanding.

*Conclusion:* based on the insights obtained from the experiment, 2 main important points that could act as factor in facilitation virtual team cognitive consensus where derived:
1. Virtual team members should not be restrained to communicate their ideas or opinions only verbally, other forms of ideas and opinions representation should be used in order to assist virtual team cognitive consensus.
2. A negotiation process to help virtual team members reach common agreement about what strategy should be used is necessary.

***Experiment # 2:***

This experiment was the same as the experiment number 1, however some improvements were made based on the insights and conclusions derived from the previous experiment, and as a result changed the scenario for this experiment.

*Objective of experiment:* to understand the difficulties virtual teams face in reaching cognitive consensus and agreement while sharing ideas /opinion during team collaboration while solving a task.

*Sample and equipment:* 4 people were invited to participate in the virtual teamwork experiment. The participants were located in different places throughout the whole experiment. All participants were university students and with an age range above 20 years old and with academic background above undergraduate degree. The team collaborated together virtually by using two main collaboration software: Miro and Zoom. Miro is an online collaborative whiteboarding platform that enables distributed teams to work effectively together, from brainstorming with digital sticky notes to planning and managing agile workflows. Zoom is a software application that provides video telephony and online chat services through a cloud-based peer-to-peer software platform and is used for teleconferencing, telecommuting, distance education, and social relations.

*Task objective:* team members worked together to solve a map puzzle. They needed to share their ideas and opinions that could help their team solve the puzzle in a very efficient way.

*Scenario:* a common virtual board was created by using the Miro software, which enables team members to collaborate real time on the same task. Every team member could access the same board from their laptops. On this board team members would write their ideas and opinions, which could be accessed by every member and also, they would use the same board to draw the map. Zoom software was used as a communication tool to help team members discuss their ideas and negotiate. Team members used videoconference to communicate with each other.

*Steps:*

1. Before the experiment began, each team member received a portion of information that would help them solve the map puzzle. That information was related to each other but were not the same. This fact by itself created the right situation for team members to share information and community with each other during the experiment.
2. Once team members were connected by Miro and Zoom software the experiment began. First, they were introduced to the overall experiment and read the instructions which were available on the Miro board. The instructions asked team members to share the information that each one received separately by writing it on the common board. Information such as "There is a John's shop in the northwest of the shop with the cherry tree" "The bakery is in the South of the butchery", were shared in the common board and every member could read and interpret the information.
3. After sharing that information, team members were asked to think about the best ways to solve the map puzzle and write their ideas and opinions on a sticky note available in Miro software and share verbally those written ideas with each other through discussion. After sharing and discussing their opinions and ideas, team members would agree on a strategy by choosing which ideas would help them in solving the puzzle by verbally voting which idea they thought was good those chosen ideas were allocated in a different section of the board which represented the ideas belonging to their team strategy.

4. After agreeing on the strategy team members began to work on solving the puzzle till the task was completed.
5. *Results:* overall team members took about 36 minutes to solve the puzzle.

*Insights from this experiment:*

1. By writing their ideas in sticky notes team members had the opportunity to better articulate their opinions before sharing with each other since the process of writing starts by carefully thinking about what we want to externalize from our minds. This made it possible for team members to write their thoughts and ideas in a very clear and understandable way.

2. Since the ideas written on stickers were placed on a common board, everyone had the opportunity to reflect others' ideas and make sense of it by going through each idea. This process helped team members understand each other better and consider diverse points of views. The second advantage was that team members were able to explain to others what they meant by that idea and why they came up with the same idea. This gives other members the opportunity to internalize different knowledge and actually consider the ones that they think will help their team solve the task.

3. By negotiating which idea would be part of their strategy team members now had obtained a common understanding on how to proceed with their work as a team by using all the selected ideas as their strategy elements and started working on solving the map. Even though the way of negotiation was not the best, it gave us a great insight on how important it is for a virtual team to have a way to negotiate what kind of knowledge they should use during their work process.

4. Even though team members could read the same task information most of the time they needed to clarify how each other interpreted the task information since their interpretation of the information were divergent.

*Conclusion:* based on the insights obtained from this experiment, 2 main important points that could act as factor in facilitation virtual team cognitive consensus where derived:

1. Writing ideas, information, knowledge or opinion on a common virtual space can help virtual team members externalize and understand and agree with each other's ideas best.
2. A process to help negotiation in a virtual team is very essential to reach cognitive consensus about the essential knowledge necessary to help solve the task at hand in virtual teams.
3. While working virtually team members need to share what is their interpretation of the task information with each other.

***Experiment #3***

*Objective of experiment*: to understand how team members interpret a given task information and how they interpret each other's ideas, opinion or knowledge when it is shared in a written format while working virtually.

*Sample and equipment:* 4 people were invited to participate in the virtual teamwork experiment. The participants were located in different places throughout the whole experiment. All participants were university students and with an age range above 20 years old and with academic background above undergraduate degree. The team collaborated together virtually by using two main collaboration software: Miro and Zoom. Miro is an online collaborative whiteboarding platform that enables distributed teams to work effectively together, from brainstorming with digital sticky notes to planning and managing agile workflows. Zoom is a software application that provides video telephony and online chat services through a cloud-based peer-to-peer software platform and is used for teleconferencing, telecommuting, distance education, and social relations. A third design software used to design coffee cups was used to help team members complete the task.

*Task Objective:* team members work together virtually to come up with ideas for a coffee cup design based on the requirement given by the client.

*Scenario:* On the Miro board 4 sections were created to allow team members to perform their work. In the first space the information about the task was allocated and available to every member to read and interpret. On the second space team members could write their ideas on how the cup design should look based on their interpretation of task information and share it with each other. On the third space team members would share a design of the coffee cup after sharing and discussing their ideas. Finally on the last space team members would design another cup after having an idea of what another member's cup design looks like.

*Steps:*

1. After reading the information team members took 5 minutes to interpret and think about what their interpretation is about the task information assigned to them.
2. Then team members took 10 minutes to write their interpretation on a sticky note available on Miro board and shared with each other.
3. After that, team members took 5 minutes to think about what would be the ideal coffee cup design that fulfilled the task requirements.
4. After thinking about those details, team members took 10 minutes to write their ideas in the stickers in a common idea space. While writing the ideas they were encouraged to write as much detail as possible about how the cup would look like
5. After finishing writing their ideas, they shared it with each other by articulating their ideas and explaining to others why they came up with those ideas
6. Once this stage was over team members took 15 minutes and used a design software to design their interpretation of the coffee cup.
7. Once everyone finished designing their interpretation of the coffee cup, they shared their designs in a common space where everyone could see. At this stage they were able to see how their idea of coffee design would vary from each other and how their interpretation about the same task information was rather divergent.

8. After reviewing the similarities and differences from each other's design they were asked to come up with a final design of the coffee cup. The main point to do that was to see if by seeing others' interpretation of the cup design their initial idea would be affected or changed at a certain level in the second attempt of designing the coffee cup. Once they finished submitting the second coffee cup design the experiment was concluded.

*Insights:*

*1.* Team members at the beginning of collaboration tend to interpret the task information in a different way, since the way members would approach a situation or task varies based on their background, experience and area of expertise.
2. Even though team members shared their ideas in a common visible space, articulated it to other members, and other members were able to see and interpret the ideas, still it was not really clear if they were interpreting the same ideas in a similar way. What we noticed is that while members shared their ideas, the other team members tended to interpret or understand those ideas in a different way. Even though team members were encouraged to share their ideas with a lot of detail, still many of those ideas were quite abstract to other, leaving room for people to interpret the meaning of those words in a very different way, that required the person who wrote the idea to further clarify the actual meaning of those idea in order for other to actually understand the meaning behind their opinions. This fact made us realize that virtual teams have a lot of difficulties in clarifying information or knowledge that have a high degree of abstraction and as a consequence team member interpretation about someone's idea may also differ. Thus, it is important that in virtual team collaboration team members have a process that facilitates the clarification of ideas to other members in such a way that the level of abstraction is reduced considerably so that team members are able to interpret each other's ideas in a similar fashion.
3. During the stage of idea sharing, ideas of two or more members were written in a similar way, and that is because team members used similar expressions or terminologies to express their ideas. Thus, this gave the impression to team members that their ideas are the same and those ideas hold the same meaning. However, when they presented their cup design to each other the details which were shared in words by using similar terminologies during idea sharing were quite different from each other even though they have used the same word to represent those details. One example is the team members interpretation of the summer theme for the cup, in which many members use the word beach as part of their design to represent the summer theme. However, the word beach can mean different things for different people. Based on their experience, preferences, and expectation when people think about the work beach the image their picture in their mind varies from each other. Even though team members used the word beach to represent their summer team, what they meant with that terminology was totally different in terms of context. For some members beach meant palm trees and blue waves, while for other members it meant umbrellas, ice cream and tropical fruits. That information was hidden still in their minds and as they used the same terminology, they expected that others were picturing the same things as themselves, which was quite the opposite. Therefore, it is important that team members besides sharing their ideas, in case the same terminologies are used they are able to clarify not only the meaning of those common terminologies but also the context of those same terminologies.

*Conclusion:*

1. *At the beginning of collaboration virtual teams should make sure that every member interprets the task information in a similar way.*
2. *Virtual teams should make sure that others interpret their ideas in the correct way and should make an effort to clarify misinterpretations once it is realized.*
3. *Virtual teams should be aware of similar terminologies used while sharing their interpretation of task information or knowledge between team members, and make sure that those same terminologies are clarified in terms of meaning and context.*

***Experiment #4***

This experiment has a similar objective as the previous one, plus an extra objective to understand how team members clarify similar terminologies used while interpreting task information and knowledge shared. Here we tried to improve what was lacking in the previous experiment, hence changing their work scenario.

*Objective of experiment*: to understand how team members interpret a given task information, how they interpret each other's ideas, opinion or knowledge when it is shared in a written format while working virtually, and how to clarify similar terminology used bt member from the same group while sharing their interpretation of task information and shared knowledge.

*Sample and equipment:* 4 people were invited to participate in the virtual teamwork experiment. The participants were located in different places throughout the whole experiment. All participants were university students and with an age range above 20 years old and with academic background above undergraduate degree. The team collaborated together virtually by using two main collaboration software: Miro and Zoom. Miro is an online collaborative whiteboarding platform that enables distributed teams to work effectively together, from brainstorming with digital sticky notes to planning and managing agile workflows. Zoom is a software application that provides video telephony and online chat services through a cloud-based peer-to-peer software platform and is used for teleconferencing, telecommuting, distance education, and social relations. A third design software used to design coffee cups was used to help team members complete the task.

*Task Objective:* team members work together virtually to come up with ideas for a coffee cup design based on the requirement given by the client.

*Scenario:* On the Miro board 5 sections were created to allow team members to perform their work. In the first section, the information about the task was allocated and available to every member to read and interpret. In the second section, team members could write their ideas on how the cup design should look based on their interpretation of task information and share it with each other. Here, team members would check if members are using similar task terminology in their written ideas and interpretation and try to clarify in case similar terminologies from different members were available. In the third section, the team would allocate similar terminologies used in their written interpretation and clarify it in terms of definition and context. In the last section team members would share a design of the coffee cup after sharing and discussing their ideas. Finally on the last space team members would design another cup after having an idea of what another member's cup design looks like.

*Steps:*

1. After reading the information team members took 5 minutes to interpret and think about what their interpretation is about the task information assigned to them.
2. Then team members took 10 minutes to write their interpretation on a sticky note available on Miro board and shared with each other.
3. After that, team members took 5 minutes to think about what would be the ideal coffee cup design that fulfilled the task requirements.
4. After thinking about those details, team members took 10 minutes to write their ideas in the stickers in a common idea space. While writing the ideas they were encouraged to write as much detail as possible about how the cup would look like
5. After finishing writing their ideas, they shared it with each other by articulating their ideas and explaining to others why they came up with those ideas
6. After sharing their ideas and interpretation team members engaged on interpreting other members ideas and making sure that they are interpreting it in a correct way. Here clarification of interpretation was done several times to ensure that everyone was on the same page.
7. Once ideas were interpreted by others and clarified, team members checked if many ideas had similar terminologies and clarified it in terms of definition and context.
8. Once this stage was over team members took 15 minutes and used a design software to design their interpretation of the coffee cup.
9. Once everyone finished designing their interpretation of the coffee cup, they shared their designs in a common space where everyone could see. At this stage they were able to see how their idea of coffee design would vary from each other and how their interpretation about the same task information was rather divergent.
10. After reviewing the similarities and differences from each other's design they were asked to come up with a final design of the coffee cup. The main point to do that was to see if by seeing others' interpretation of the cup design their initial idea would be affected or changed at a certain level in the second attempt of designing the coffee cup. Once they finished submitting the second coffee cup design the experiment was concluded.

*Insights:*

1. Interpreting others’ ideas and making sure that the interpretation was correct was very helpful in facilitating similar knowledge cognition among team members.
2. Identifying and clarifying the use of similar terminology in terms of definition and context while team members share thirty ideas and knowledge was very essential to ensure that team members have a common understanding about their intentions.

Based on those finding obtained from those experiments 3 main factors that contribute in improving and facilitating cognitive consensus of virtual team members during knowledge sharing process have been identified:

*-Interpretation of other team members' knowledge, information, and ideas.*
*-Agreement on common verbal information*
*-Negotiation about group interpretation*

Furthermore, researchers were done on those 3 factors in other to understand their importance in facilitating virtual team cognitive consensus and those are the findings:

**Factor 1: Interpretation of other team members' knowledge, information, and ideas**

Previous research done in the area of cognitive conflict has supported the theory of Region of Validity. This technique consists of describing others point of view or argument which is believed to help reduce cognitive conflict between individuals when sharing knowledge (Rapoport 1961, 1964). Group activities such as: (i) accurately restation other person's point of view, (ii) stating reason for agreeing with a specific point in the person's argument, (iii) understanding the areas where they disagree the most, and (iv) making positive remarks about other member opinion, can help reduce cognitive conflict during knowledge sharing process. (Hammond, K. R., Todd, F. J., Wilkins, M., & Mitchell, T. O. (1966)).

Nonetheless, the use of this concept in our process process will be of great importance since it supports the findings observed during the previous experiments. We believe that the ability for a person to focus not only on his/her point of view but also to objectively and explicitly consider other's point of view by interacting and interpreting what other members share could facilitate the development of cognitive consensus in virtual teams.

**Factor 2: Agreement on common verbal information**

Previous researchers done in the area of team cognitive concordance introduce the theories of Illusory Concordance and Superficial Discordance in teams. Illusory concordance refers to the state in which team members agree in a conscious level about a common topic but disagree in a subconscious level about the same topic, meaning that team members may say things that make them think that they agree with each other but in their subconscious, they have different expectation about the same thing. (Healey, M. P., Vuori, T., & Hodgkinson, G. P. (2015)). This phenomenon happens often in groups made of individuals who have different educational backgrounds and professional experience, in which different terminologies, expressions, and verbal information related to the task are used. In this kind of situation individuals with different areas of expertise may use the similar expression, terminologies or words to explain the same concept, however, due to their different areas of expertise the definition and context of the terminology may differ from each other. And when a situation like this is unnoticed team members may end up having a hard time to reach cognitive consensus.

On the other hand, surface discordance is the opposite of illusory concordance. Here, team member may use different definitions when referring to the same terminology, giving the impression that they are discussion different concepts when in reality they are talking about same thing but define it using with different expressions ((Healey, M. P., Vuori, T., & Hodgkinson, G. P. (2015))

Research done on elicitation of knowledge from experts found that experts often have the problem of sharing only parts of their terminologies and conceptual systems. Experts tend to use the same term for different concepts, use different terms for the same concept, use the same term for the same concept, or use different terms and have different concepts. (Shaw, M. L. G., & Gaines, B. R. (1989).

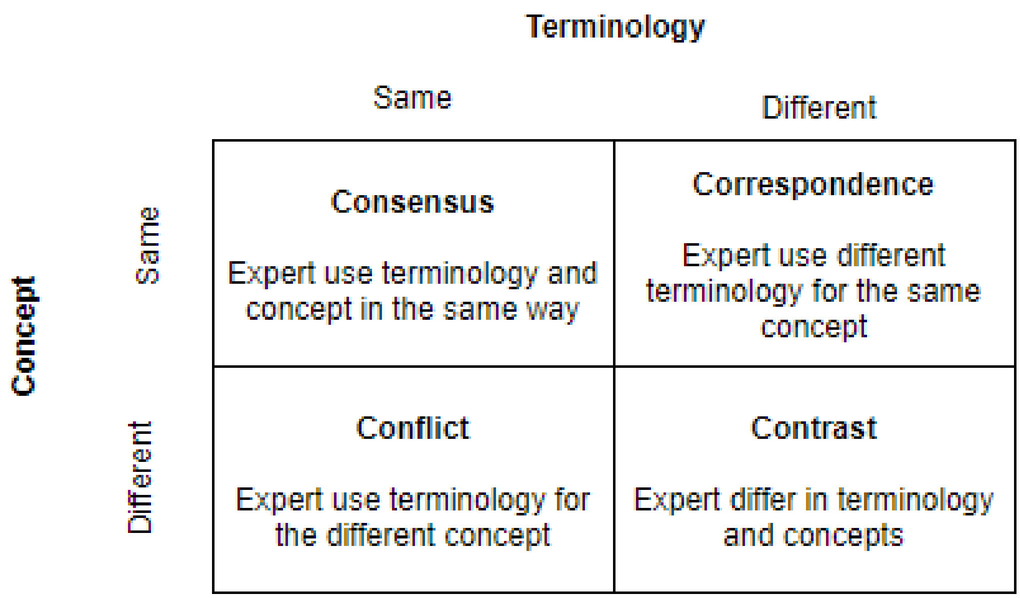


Fig.3 Consensus, conflict, correspondence and contrast among experts. Source: Shaw, M. L. G., & Gaines, B. R. (1989).

As a result, in a knowledge sharing process during virtual collaboration, it is critical not to attempt to impose a false consensus among the team members under the guise of "proper" language and conceptual framework. However, it is equally critical to highlight discrepancies among specialists and make these publicly available for discussion. Some of these may represent elicitation mistakes, while others may reflect discrepancies in language or conceptual frameworks. In any case, discussing these disparities is an important element in the knowledge elicitation process.

**Factor 3: Negotiation about group interpretation**

Negotiation is defined as a collaborative method to dispute resolution that involves exploring all options in order to achieve maximum satisfaction for all parties (S. Easterbrook, 1991). When in a team members have different opinions about the task at hand, having a negotiation system that allows teams to agree on a common task interpretation, facilitates decision making and conflict resolution. (Duecker, M., Gutkauf, B., & Thies, S. (1999)). Thus, for our process we will include a negotiation process that will facilitate agreement between members of the virtual team about the interpretation of the task process.

## 3.3. Process Flow

Beside the factors affecting cognitive consensus in virtual teams, for the design of our proposal other factors were taken into consideration in order to define the process flow:

1. **Type of knowledge shared**

   Previous research has classified the knowledge shared in teams into two types: explicit and tacit knowledge. Explicit knowledge is defined as information that can be recorded and described in words and numbers and disseminated as data in the form of courses or books for self-study, scientific formulas, specifications, manuals, and so on (Seubert et al. (2001)). This type of information may be easily and formally shared between persons. Tacit knowledge is knowledge that is exclusively known by one person and is difficult to transmit to the rest of an organization. According to Nonaka and Konno (2000), tacit knowledge is firmly embedded in an individual's actions and experiences, as well as the beliefs, values, or emotions that he or she accepts.

   In our process we consider both explicit and tacit types of knowledge shared. For explicit types of knowledge, documents describing task information and task requirements will be shared. On the other hand, opinions, interpretation, point of view, will be the type of tacit knowledge considered when virtual teams use our proposed process. (Goffin et al., 2010: 41))

2. **Type of mental model**

   Based on previous research, mental models are classified into two categories: task related mental model and members-related mental model. Task-related SMM highlights the team's knowledge and substance of certain works, such as task prediction, judgment criteria, and sense of progress, task strategy, task process and others(Xiang, C., Yang, Z., & Zhang, L. (2016)). Member-related mental models are concerned with how individuals will collaborate and coordinate with other teammates to complete the task, such as having comparable knowledge backgrounds and understanding their colleagues' expertise, duties, and so on. ((Xiang, C., Yang, Z., & Zhang, L. (2016)).)

Our process however, will focus only on task-related mental models. The reason for that is because previous research done on the types of conflicts in teams, have concluded that in virtual team's cognitive conflict appears to be higher than in collocated teams (Chiravuri, A., Nazareth, D., & Ramamurthy, K. (2011)). Other research suggests that task-based conflict might help groups work more effectively by encouraging open debate and consideration of a larger range of options (Wakefield, 2008). Because virtual teams lack face-to-face connection, they may be more focused on the job at hand and experience more task-related disputes (Eisenhardt, 1990).

We focus on the mental models linked to the work at hand for the purposes of this study since shared knowledge of the task's mental models will lead to common interpretations of a team's processes and objectives, decreasing cognitive conflicts. (Chiravuri, A., Nazareth, D., & Ramamurthy, K. (2011)). Because disagreement between experts with distinct mental models is largely caused by differences in cognition, it is fair to assume that focusing on clarifying cognitive-task related mental models may be useful in resolving such conflicts and improving cognitive consensus in virtual teams.

## 3. Negotiation tool

We have already discussed the importance of negotiation in virtual teams to help reduce cognitive conflicts during the knowledge exchange process. The system for negotiation uses for our process was borrowed from previous studies done on the concepts of Fuzzy logic and Fuzzy mapping.

Fuzzy-graph structures (FCMs) are used to express an individual's causal reasoning by externalizing their knowledge in the form of concepts and linking the concepts in terms of degree of causation. Because of their fuzziness, hazy degrees of causation between hazy causal concepts are possible. FCMs are particularly useful in soft knowledge fields (e.g., political science, military science, history, international relations, and organization theory), where both system concepts/relationships and meta-system language are inherently ambiguous. (Kosko, 1985).

> Generally, causation in fuzzy maps is hazy. Causality allows for degrees, although vague ones. It occurs partially, sometimes, infrequently, often, more or less, and so on. More broadly, the promise of cognitive maps for knowledge base construction is integrating knowledge sources' cognitive maps, but the combined knowledge's fuzziness increases to the fuzziness of the fuzziest source of knowledge (Kosko, 1985).

When linking concepts in fuzzy maps experts represent causality by rating the level of impact of one concept against another by using the fuzzy scale which can vary for -1,0,1 range, where value from -1 to 0 means that the concept has a negative causation, values equal to 0 means that concept has a neutral causation and values from 0 to 1 means that concept has a positive causation (Özesmi, U., & Özesmi, S. L. (2004)).

In our process we will be using the fuzzy mapping rating scale as a mechanism to help team members negotiate whenever there is some kind of task-related cognitive conflict. Based on the factors facilitating cognitive consensus in virtual teams the following process flow is proposed:

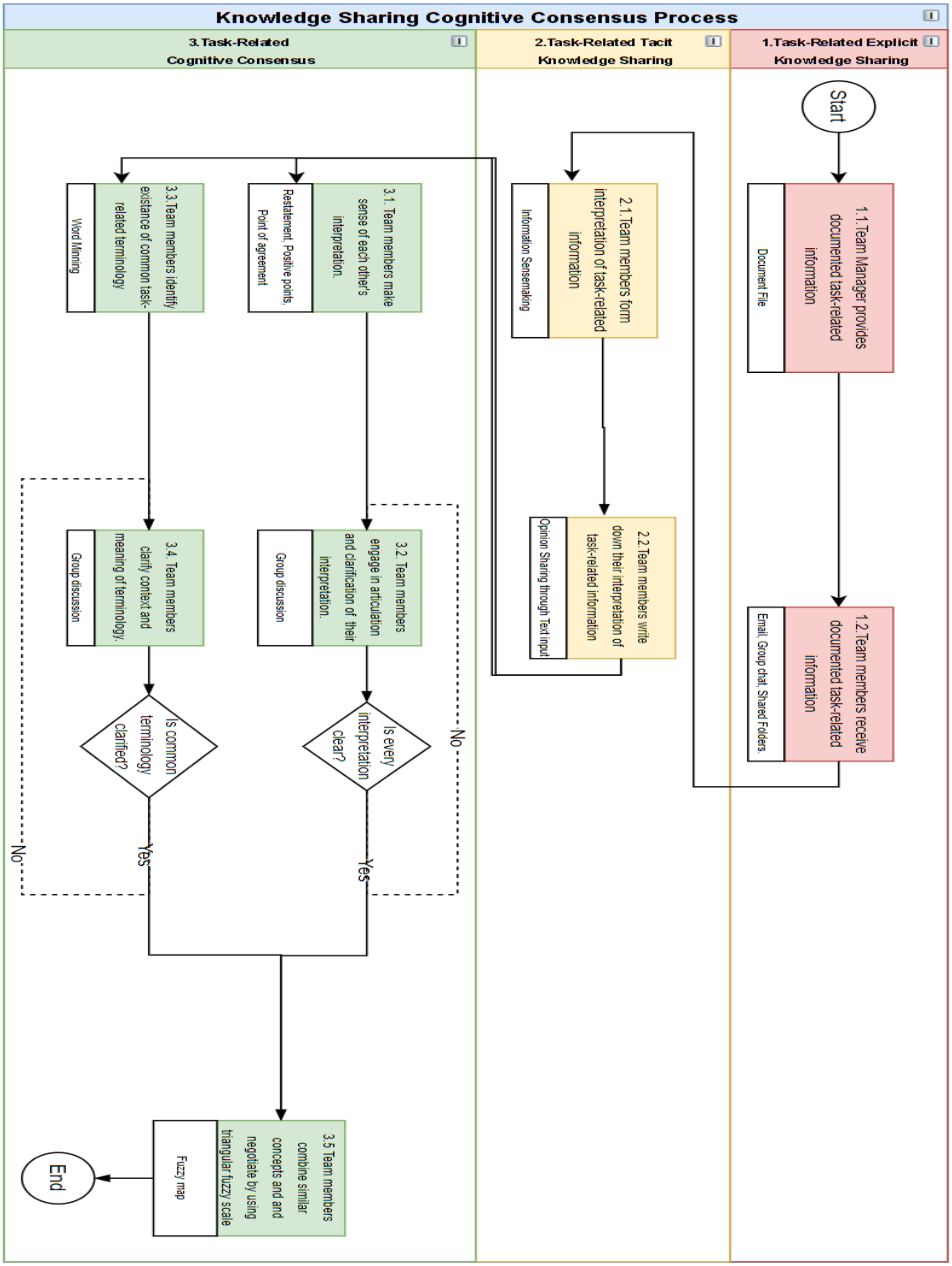


Fig.4 Process Proposal (Knowledge Sharing Cognitive Consensus Process)

## 3.4. Process Description

The proposed knowledge sharing consensus process for virtual team consists in 3 main activities:
-*Task-related Explicit Knowledge Sharing*
-*Task-related tacit Knowledge Sharing*
-*Task-related Cognitive Consensus*

### *3.4.1. Task-related Explicit Knowledge Sharing*

Task-related explicit knowledge sharing will be the first stage of the process of knowledge sharing cognitive consensus. It will consist in sharing task-related knowledge in an explicit format such as documents, files, emails, and so on. During task-related knowledge sharing two activities will take place: (i) Manager will provide task information in a document format, (ii) Team members will receive the task information document.

### *3.4.2. Task-related Tacit Knowledge Sharing*

Task-related tacit knowledge sharing will be the second stage of the process. Here team members will share their tacit knowledge in form of opinions, ideas, expectation and interpretations about the task information they have received. During this stage two main activities will take place: (i) Team member will form interpretation of task information, (ii) Team members will write down information of task-related information.

*Interpretation of task information:* this activity will enable team members to start forming their first opinion, understanding, and interpretation about the task at hand. Based on their background, experience and knowledge, team members will start forming expectations on how to proceed with the work at hand. I t is expected that those expectation will diverge from member to member.

*Writing down their interpretation of task information:* once team members have formed their assumption about the task at hand based on their interpretations, they will write down those assumptions. We are choosing for member to write down their assumption because previous research has already pointed out the benefits of team members virtually to write down their opinion and ideas since it helps and facilitate the externalization of tacit knowledge during virtual collaboration. (El-Den, J., & Sriratanaviriyakul, N. (2019)). Another benefit of this practice is that it will give the opportunity to other members in the virtual team who are not comfortable in sharing their ideas or opinions because of several personal reasons to share knowledge. Also, it will enable team members to interpret each other's information in a much easier way, since all shared knowledge will be available in a written format, compared to when members only share tacit knowledge by speaking.

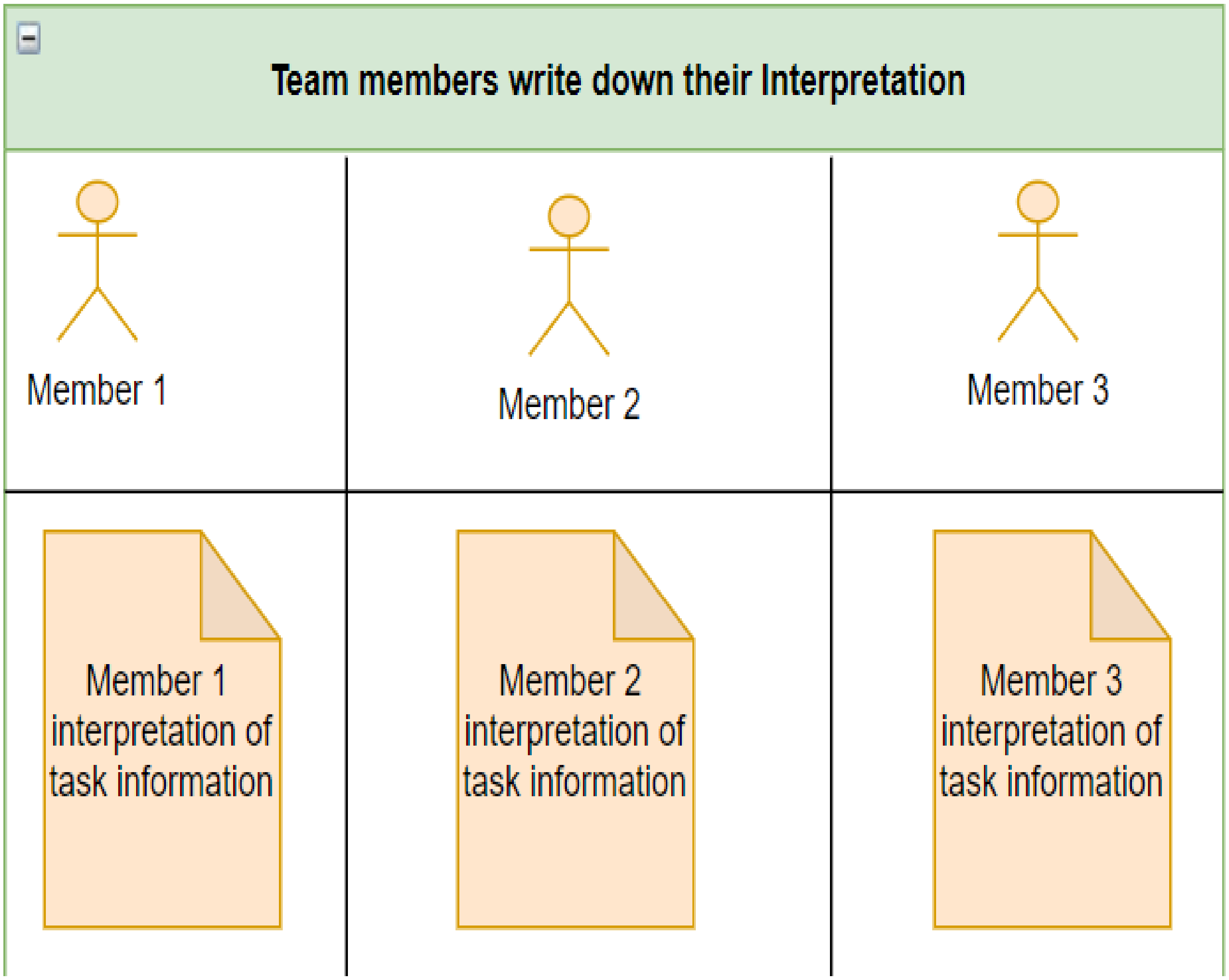


Fig. 5 Team members write down their interpretation output

### *3.4.3. Task-related Cognitive Consensus*

This will be the last stage of our process. During this team members will go through several activities based on factors facilitating virtual team cognitive consensus. The objective of these activities is to help team members develop consensus about the task-related knowledge shared during their virtual interaction during the previous activities. At this stage team members will realize team main activities:

*Team members will make sense of each other's interpretations:* as discussed in previous content from literature review, interpreting other members' arguments helps in reaching consensus in teams. Here, team members will have the opportunity to understand others' opinions, ideas and arguments. This can help reveal how much team members understand what each other is trying to communicate or convey.

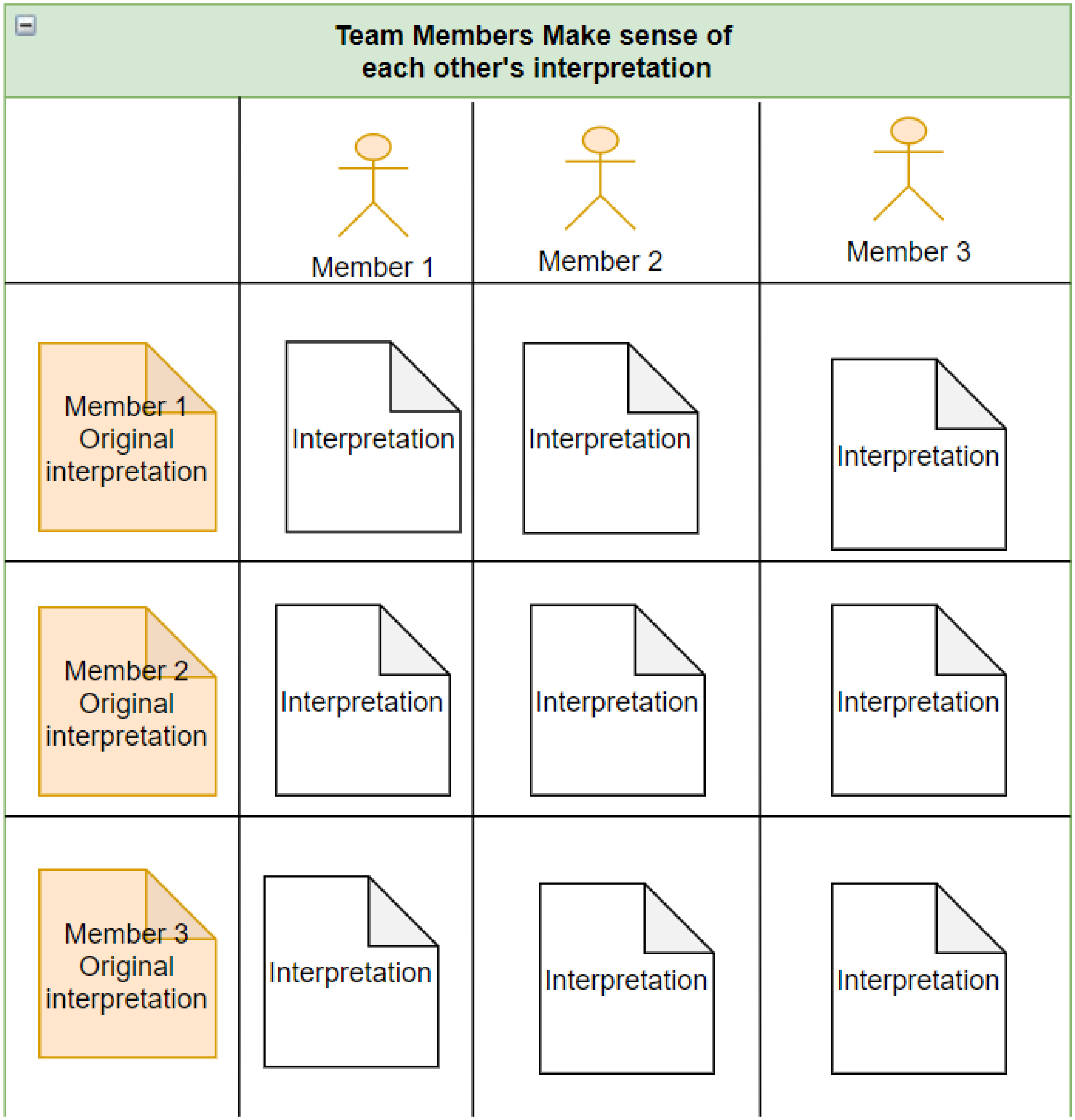


Fig. 6 Team members make sense of each other's interpretation output

*Team members will engage in articulation and clarification of their interpretations:* this activity will help team members clarify if indeed others understood what they mean in order to reduce the level of misunderstanding, misinterpretation and miscommunication of knowledge during collaboration. In case team members realize the existence of misunderstanding, they will have the opportunity to clarify it by discussing and explaining the real and correct meaning of their argument.

*Team members will identify the existence of common task-related terminology:* during this activity team members will use another important factor that facilitates team cognitive consensus and reduces task cognitive conflict. As mentioned in previously, team members during knowledge sharing activities may use the same terminology while sharing their interpretation of task information. And many times, in those situations team members may not be aware of the existence of illusory concordance and superficial discordance. In order to reduce these two phenomena, we propose this activity by allowing team members to check whether in their group there is the existence of members who share ideas, knowledge or interpretation by using similar terminologies or words. These two formal activities will be happening in a parallel sequence since both activities can happen at the exact same time during the team collaboration.

*Team members clarify context and meaning of terminology:* clarifying similar terminology used by experts in terms of meaning as well as context have shown to help reduce cognitive conflicts. Here, we want to reveal the real meaning and context of similar terminology used by members from the same team. By doing so, team members will be aware if they are talking about the exact same thing or not. This practice has proven to reduce both superficial discordance and illusory concordance in teams.

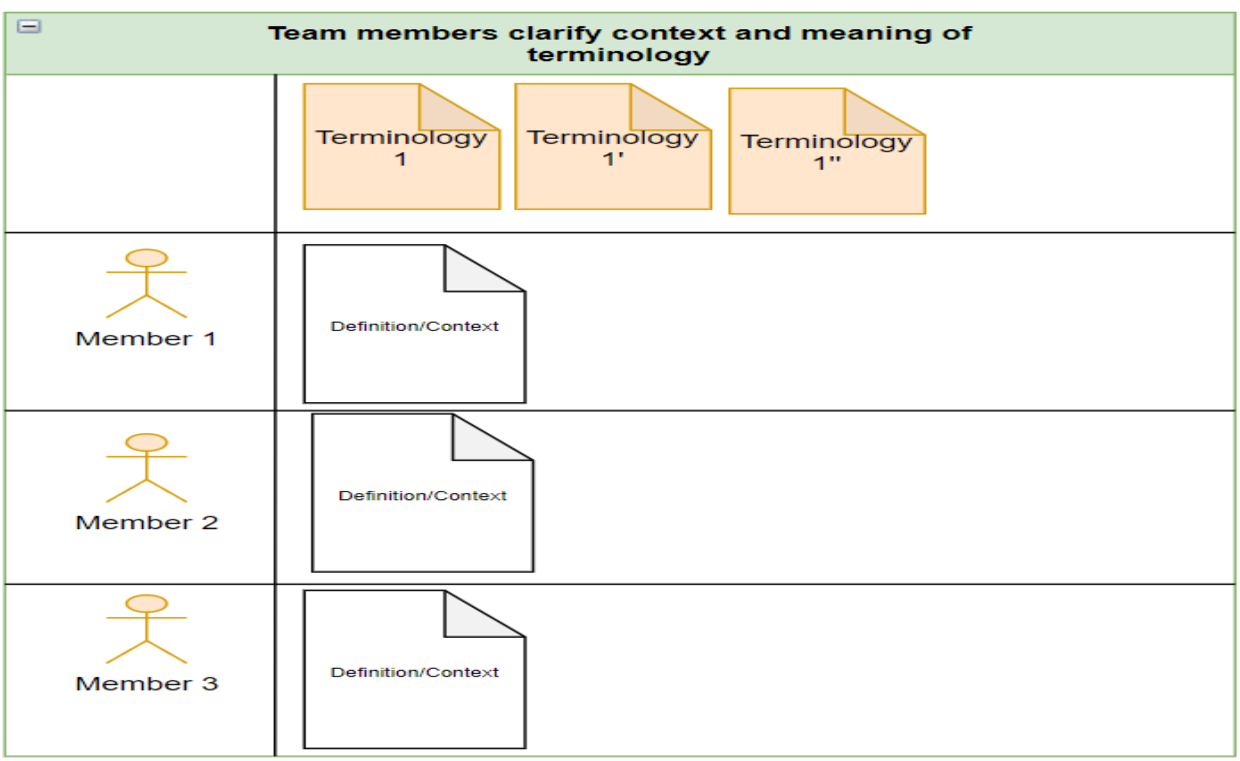


Fig. 7 Team member clarify context and meaning of terminology output

The same way these two formal activities will take place in a parallel sequence since they may happen at the same time during the utilization of the proposed process.

Two conditions were placed after sub activities, "Team *members will engage in articulation and clarification of their interpretations"* and *"Team members clarify context and meaning of terminology"* are finished. Those conditions state the following:" Is *every interpretation clear?" and "is every common terminology clarified?"*

Both conditions will check whether team members indeed have fulfilled the previous activities that are used to reduce the cognitive conflicts during knowledge sharing. If team members realize that they were not able to fulfill these conditions, they will return and repeat the previous activities until they fulfill the conditions. These conditions will ensure that every or at least most of the cognitive conflict and misunderstandings in the team has been eliminated or reduced to a certain degree.

*Team members combine similar ideas and negotiate using fuzzy map rating:* this is the last activity on this stage. Here team members will combine similar ideas or concepts and negotiate the importance of those ideas or concepts to help in achieving task goals by using the fuzzy mapping rate discussed in previous chapters. The fuzzy mapping rating scale will be the negotiation system adequate for virtual teams, since it is based on people's real and honest interpretation of the world or their surroundings and it can be rated in an anonymous way, which will avoid biased rating since peer pressure will be out of context.

# 4. RESEARCH EVALUATION

## 4.1. Evaluation Overview

To test the proposed process, experiments were conducted to examine the effects of cognitive consensus in virtual team collaboration to facilitate common interpretation and understanding during the knowledge sharing process. Two groups were created in which teams from each group used one of each mode. The first mode of knowledge sharing process is based on the proposed process and the second mode of knowledge sharing uses the traditional process.

The proposed process of knowledge sharing consists of three main activities which are: task related explicit knowledge sharing, task related tacit knowledge sharing and task related cognitive consensus. On the other hand, the traditional knowledge sharing process only consist of task related explicit and task related tacit knowledge sharing.

Two Groups A and B were formed in order to experiment in a virtual environment. Each Group consists of 5 teams with three members in each team, having in total 10 teams and 30 members. The technologies used to perform virtual team collaboration occurred via zoom video conference call for team communication and Miro white board to facilitate team knowledge sharing. Each member participating in the experiment were geographically displaced, and collaborated by using their personal computers in order to replicate the normal virtual work conditions.

After the experiment was conducted data were collected manually from the virtual boards and through survey. Verification and validation were assessed through the use of quantitative and qualitative methods. In Order to proceed with verification and validation results from the proposed process were compared against that of the traditional process of knowledge sharing. The verification process was conducted by calculating the average fuzzy weight of the concepts generated during the experiments and by determining the level of consensus among team members ratings. The validation process was conducted by determining the percentage of high consensus level, medium consensus level and low consensus level of the teams in each group. Validation was also conducted in a qualitative manner, by accessing the participants' response about their level of satisfaction during group discussion while using either process, and their perception of how much other members had understood their opinions.

For the proposed process it was expected that the teams from Group A would achieve a higher level of cognitive consensus of the knowledge shared during team collaboration compared to teams in Group B.

## 4.2. Verification

The IEEE 10122012 defines Verification as "(A) The process of assessing a system or component to evaluate if the results of a given development phase fulfill the requirements established at the start of that phase." (B) The process of providing objective evidence that the system, software, or hardware and its associated products conform to requirements (e.g., for correctness, completeness, consistency, and accuracy) for all life cycle activities during each life cycle process (acquisition, supply, development, operation, and maintenance); and satisfy standards, practices, and conventions during the life cycle process (acquisition, supply, development, operation, and maintenance), satisfy standards, practices, and conventions during life cycle processes; and successfully complete each life cycle activity and satisfy all the criteria for initiating succeeding life cycle activities. Verification of intermediate work products is required for appropriate understanding and appraisal of the life cycle phase product (s). (IEEE Computer Society, 2012).

In order to verify the accurate functionality of the proposed process 3 main variables where used:
-Fuzzy Scale
-Average Fuzzy Weight
-Level of Consensus

**The study**

**(i) Fuzzy Scale**: It is a technique from Fuzzy Logic which experts use to rate the performance achieved from each criterion or concepts generated while building a fuzzy map. These concepts are representation of people's opinion, ideas, understanding and beliefs about certain topics which are essential for the decision-making process inside a group of individuals working together to solve a certain problem. (Guh, Y.-Y., Po, R.-W., & Lee, E. S. (2008))

The fuzzy scale used in this research was adapted from (Habbib,Jahantigh and Sarafrazi, 2015), used for forecasting and screening items or concepts in terms of importance through experts opinion. In this research fuzzy scales were converted in terms of importance by using the triangular fuzzy numbers for five-point scale.

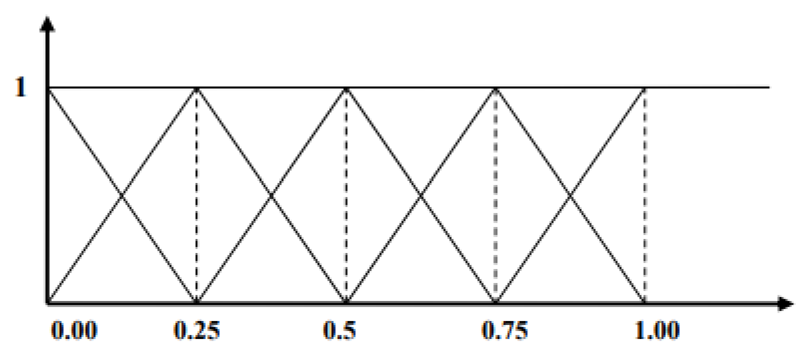


Fig.8 Triangular fuzzy number for five-point scale

By converting the linguistic expressions in terms of importance to fuzzy scale the following table was obtained:

Table 3. Triangular fuzzy number for five-point scale

| Linguistic Expression | Fuzzy Number |
|---|---|
| Very Important | (0.75, 1, 1) |
| Important | (0.5, 0.75, 1) |
| Moderately Important | (0.25, 0.5, 1) |
| Unimportant | (0, 0.25, 0.5) |
| Very Unimportant | (0, 0, 0.25) |

By using fuzzy aggregation of expert's opinion, if the opinion of experts is displayed as a triangular fuzzy number (l,m,u), fuzzy average of expert's opinion was calculated for each linguistic expression by using the following formula:

$$\text{Favg} = \frac{l+m+u}{3}$$

By doing so the following table of scale was obtained in terms of range:

Table 3. Cognitive Fuzzy Rate – 5 Points Scale

| | |
|---|---|
| Very Important for the task | 1-0.9 |
| Important for the task | 0.89-0.75 |
| Moderately important for the task | 0.74-0.49 |
| Unimportant for the task | 0.4-0.25 |
| Very unimportant for the task | 0.24-0 |

**(ii)Average Fuzzy Weight**: Reflects the relative importance of each criterion or concept for a cluster of relevant criteria. ((Guh, Y.-Y., Po, R.-W., & Lee, E. S. (2008)). By calculating the average fuzzy weight of a number of scored concepts we are able to determine the level of importance from that concept depending on the expert's perception relative to the level of importance. in this research a concept is scored by a number of experts and the average weight value is above 0.5 (Guh, Y.-Y., Po, R.-W., & Lee, E. S. (2008)).

Concept is considered to be important to the experts. Similarly, if a concept is scored by a number of experts and the average weight value is below 0.5, then that concept is considered to be unimportant to the experts.

$$Cn=\left[\frac{Fuzzy\ Weight\ M1+Fuzzy\ Weight\ M2+Fuzzy\ Weight\ M3}{3}\right]$$

Where:
Cn- Concept number
M1= fuzzy weight given by member 1
M2= fuzzy weight given by member 2
M3= fuzzy weight given by member 3

**(iii)Level of Consensus:** The level of consensus in this thesis was calculated by adapting a method used in (Irdayanti, Abdullah and Ramlee, 2014). In this paper interquartile range was used to understand the difference of opinion between experts in answering a questionnaire by scoring items using five-point likert. The consensus level is determined based on a consensus interquartile range. This method helped determine the level scale of experts' agreement from high consensus, medium consensus and no consensus/lower consensus.

In this paper the interquartile range of the total weight values of concepts was calculated to determine the medium level of consensus value between experts rating.

Q2 (Medium Quartile Range)
Q1(Lower Quartile Range)
Q3 (Higher Quartile Range)
Interquartile range (IQR) = (Q3-Q1)=Medium Consensus Level

Then the consensus level of experts rating for a single concept was calculated by using the following formula:

$$Cn=(Highest\ Fuzzy\ Weight\ Value\ -\ Lowest\ Fuzzy\ Weight\ Value)$$

Where:
Cn- Concept number

**The task:**

The task given to each team in groups was to build a system that allows the people around the world to virtually cheer for their country during the Olympics games as due to the Covid -19 Pandemic restrictions it is difficult for people around the world to witness the game physically. Therefore, the team was asked to think about what kind of activities would help the team to build such a system. Activities are a series of instructions or steps which are used to help team members complete a task process.

**Sampling and data collection**

*The members*

To verify the proposed process a total of 24 members participated in a virtual teamwork experiment, each group had a total member of 4 teams with 3 members on each team. Members who participated in the experiment belong to the department of System Design and Management at Keio University, wherein majority of the participants are males 66.7% and 33.3% females. Their age range varied from 20 to 60 years old. Most of the participants have professional experience varying from the field of engineering to humanities. Furthermore, majority of the participants have between 1 to 20 years of face-to-face teamwork experience, however majority of participants have reported to have only between 1 to 2 years of virtual teamwork experience.

*Equipment*

Team members worked virtually from different geographical locations by using their laptops. The team collaborated together virtually by using two main collaboration software: Miro and Zoom. Miro is an online collaborative whiteboarding platform that enables distributed teams to work effectively together, from brainstorming with digital sticky notes to planning and managing agile workflows. Zoom is a software application that provides video telephony and online chat services through a cloud-based peer-to-peer software platform and is used for teleconferencing, telecommuting, distance education, and social relations.

Table 4. Sample demographics

| Variables | Categories | Count | Percentage |
|---|---|---|---|
| Gender | Male | 16 | 66.7 |
| | Female | 8 | 33.3 |
| Age | ≥ 25 | 1 | 4.4 |
| | 26-30 | 3 | 12.5 |
| | 31-40 | 11 | 45.8 |
| | <40 | 9 | 37.5 |
| Field of work | Government | 6 | 25 |
| | Business and Management | 5 | 20.8 |
| | Architecture and Engineering | 3 | 12.5 |
| | Education | 2 | 8.3 |
| | Art, Culture and Entertainment | 1 | 4.1 |
| | Communication | 1 | 4.1 |
| | Community and Social Services | 1 | 4.1 |
| | Science and Technology | 1 | 4.1 |
| | Health and Medicine | 1 | 4.1 |
| | Others | 3 | 12.5 |
| Years of work experience | 0 years | 1 | 4.1 |
| | 1-10 years | 8 | 33.3 |
| | 11-20 years | 9 | 37.5 |
| | 21-30 years | 4 | 16.6 |
| | <30 years | 2 | 8.3 |
| Years of teamwork experience | 0 | 1 | 4.1 |
| | 1-10 | 9 | 37.5 |
| | 11-20 | 10 | 41.6 |
| | 21-30 | 4 | 16.6 |
| Years of virtual teamwork experience | 0 | 6 | 25 |
| | 1-2 | 14 | 58.3 |
| | 3-4 | 1 | 4.1 |
| | 5-6 | 1 | 4.1 |
| | 7-8 | 0 | 0 |
| | 9-10 | 2 | 8.3 |

**Procedure and teams**

To verify the proposal, A total of 2 groups were formed with 4 teams in each group and each team consists of 3 members. The two groups were named Group A and Group B. Group A used the proposed process to collaborate and Group B used the traditional process to collaborate. A comparison between the two groups was made to determine which process better facilitates the development of cognitive consensus during knowledge sharing activities in virtual collaboration. The data obtained from one team from each group were not taken into consideration during the verification and validation process since both teams have failed to rate the concepts accordingly. In total the data of Four teams of each group were considered for the verification and validation process.

**(i) Group A**

-***Step1***: Team members from Group A took 5 minutes to read the task information and carefully think about activities that would help their teams build the system.

> **Task Information**: Due to the COVID-19 pandemic some restriction where imposed which made it difficult for people around the would to travel to Japan and enjoy the Olympic Games. People around the world still want to celebrate the Olympic Games and cheer for their country' athletes competing in the different categories of games. A system that allows people around the world to virtually cheer for their country during the games is needed and your team is assigned to build this system.
> **Please think about what kind activities would help your team build this system. Activities are series of steps or tasks that will help your team in completing the assignment.**

Fig. 9 Step 1 Group A illustration

-***Step2:*** Then team members took 10 minutes to write down the activities in stickers available in the Miro board in their individual work space.

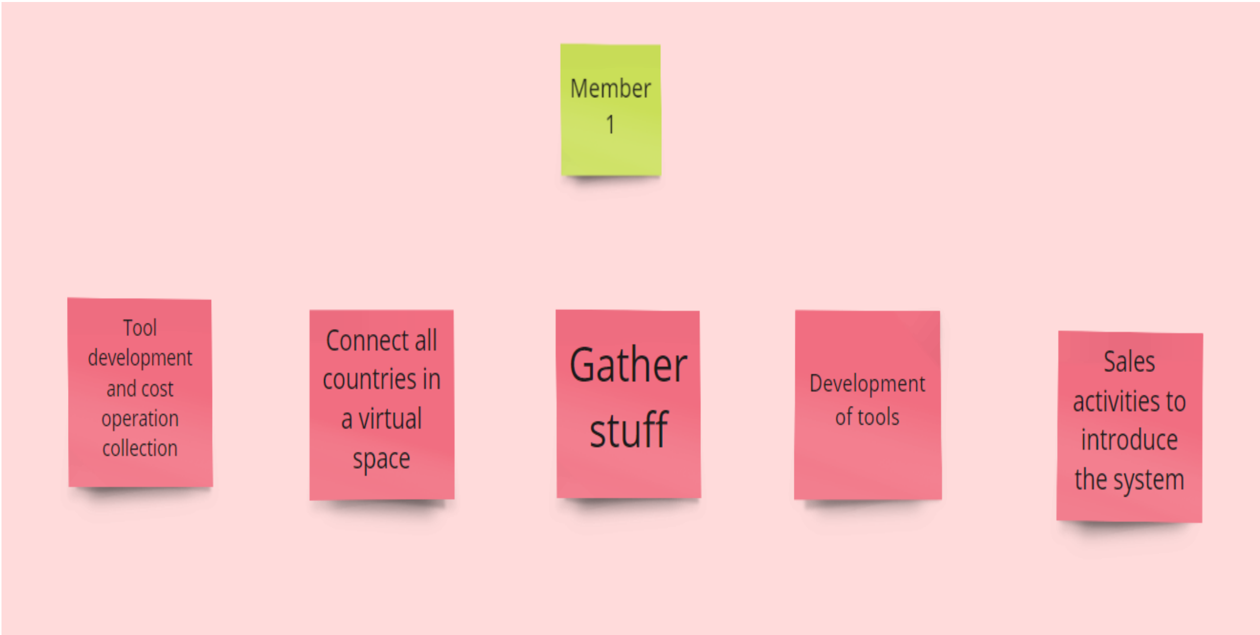


Fig. 10 Step 2 Group A illustration

- ***Step3:*** Team members copied the activities and placed them in the interpretation table, organizing each activity by number.

-***Step4:*** Team members took 30 minutes to write down their interpretation of other member's activities and shared with each other. At this stage team members made sure that everyone could interpret the activities they wrote in a similar and accurate way by clarifying the misinterpretation while discussing.


Fig. 11 Step 4 Group A illustration

- ***Step5:*** During the interpretation of other member's activities, if team members noticed that some activities were written in a similar way by using similar terminologies, those activities were allocated in the clarification of context and meaning table. Meaning of a word is how team members defined the terminology and context is what the member pictures while using the terminology.

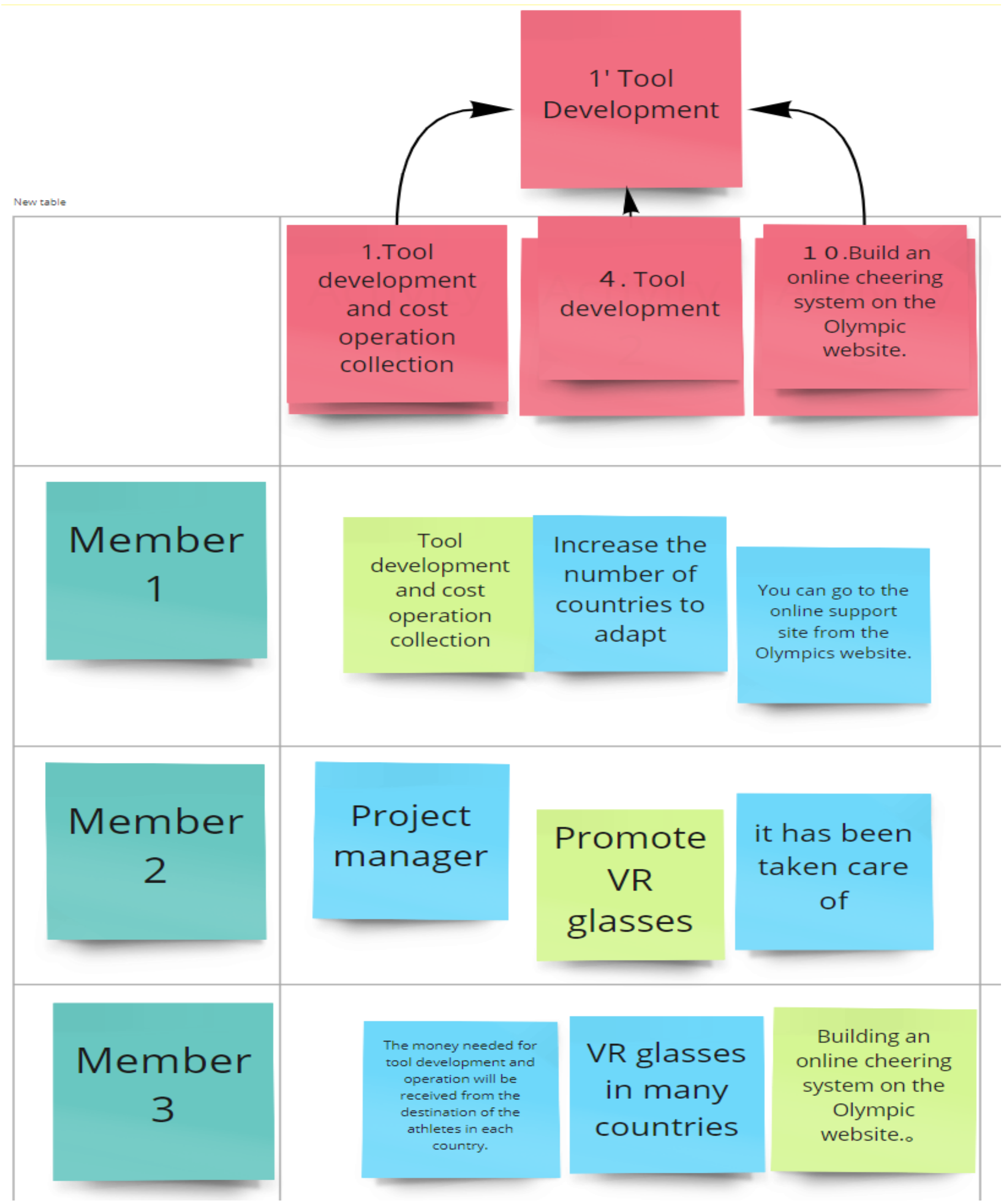


Fig. 12 Step 5 Group A illustration

***-Step 6***: If the activities have the same meaning and context, these activities should be combined into unique activities. if activities have different meaning and context those activities should be considered as different. If meaning and context of one activity is part of the other activity then they should be combined too.

-***Step 7:*** Team members took 5 minutes to select all activities and build a Fuzzy map with the task process as the center of the map by using the Fuzzy scale provided.

-***Step 8:*** Team members took 10 minutes to copy the fuzzy map in their individual work space and rated each concept based on their perception of how important each concept is for the task.

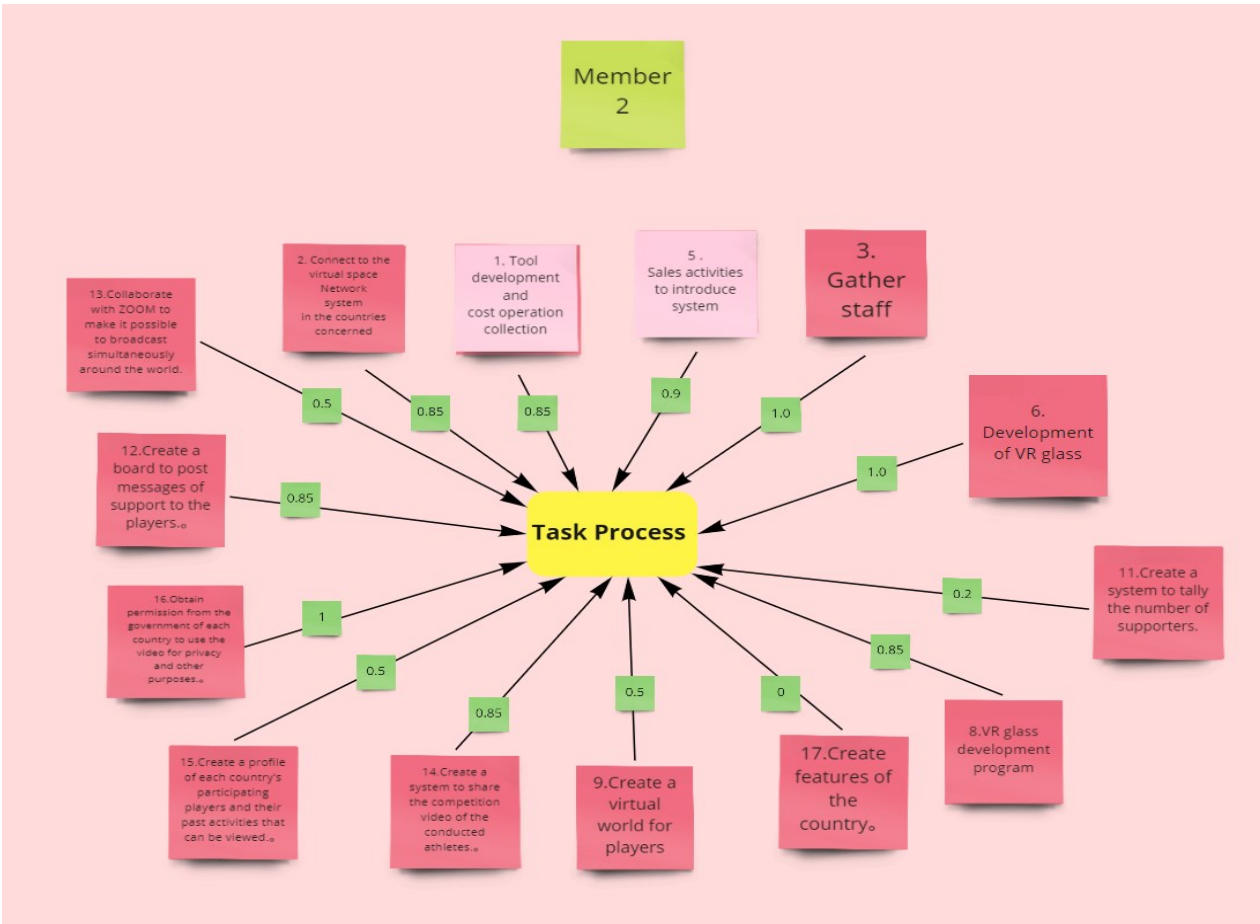


Fig. 13 Step 8 Group A illustration

-***Step 9:*** Team members then answered the survey to gauge how satisfied they were with the discussion and how their opinions were understood by the others.

**(i) Group B.**

-***Step1***: Team members from Group A took 5 minutes to read the task information and carefully think about activities that would help their teams build the system.

> **Task Information**: Due to the COVID-19 pandemic some restriction where imposed which made it difficult for people around the would to travel to Japan and enjoy the Olympic Games. People around the world still want to celebrate the Olympic Games and cheer for their country' athletes competing in the different categories of games. A system that allows people around the world to virtually cheer for their country during the games is needed and your team is assigned to build this system.
> **Please think about what kind activities would help your team build this system. Activities are series of steps or tasks that will help your team in completing the assignment.**

Fig. 14 Step 1 Group B illustration

-***Step2:*** Then team members took 10 minutes to write down the activities in stickers available in the Miro board in their individual work space.

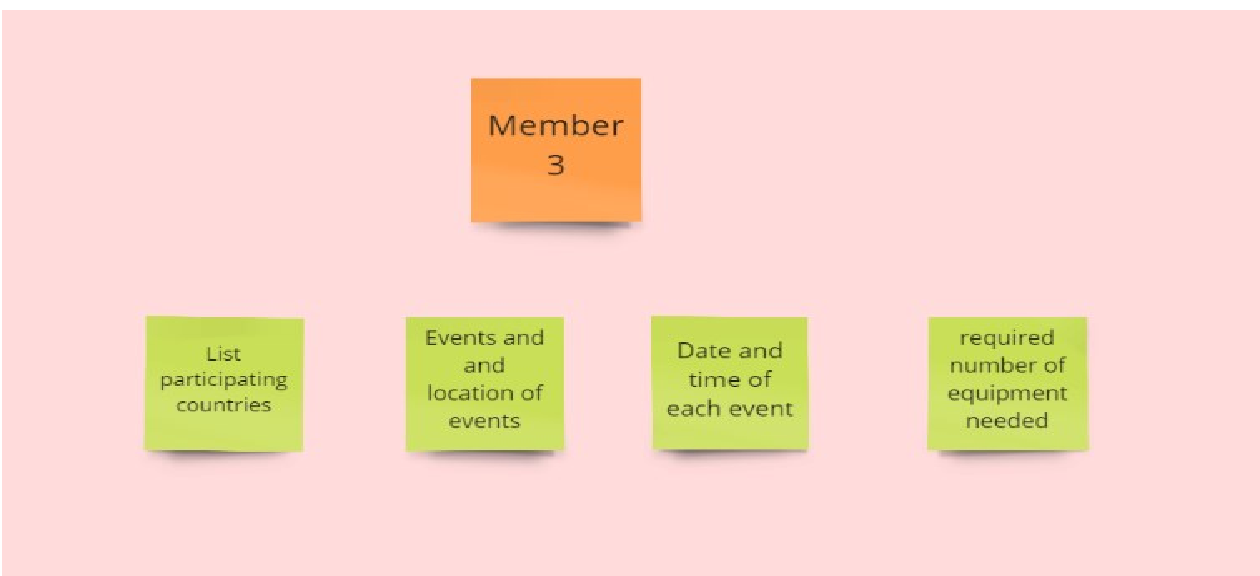


Fig. 15 Step 2 Group B illustration

- ***Step3:*** Team members copied the activities and placed them in a common board and organized the activity by numbers.

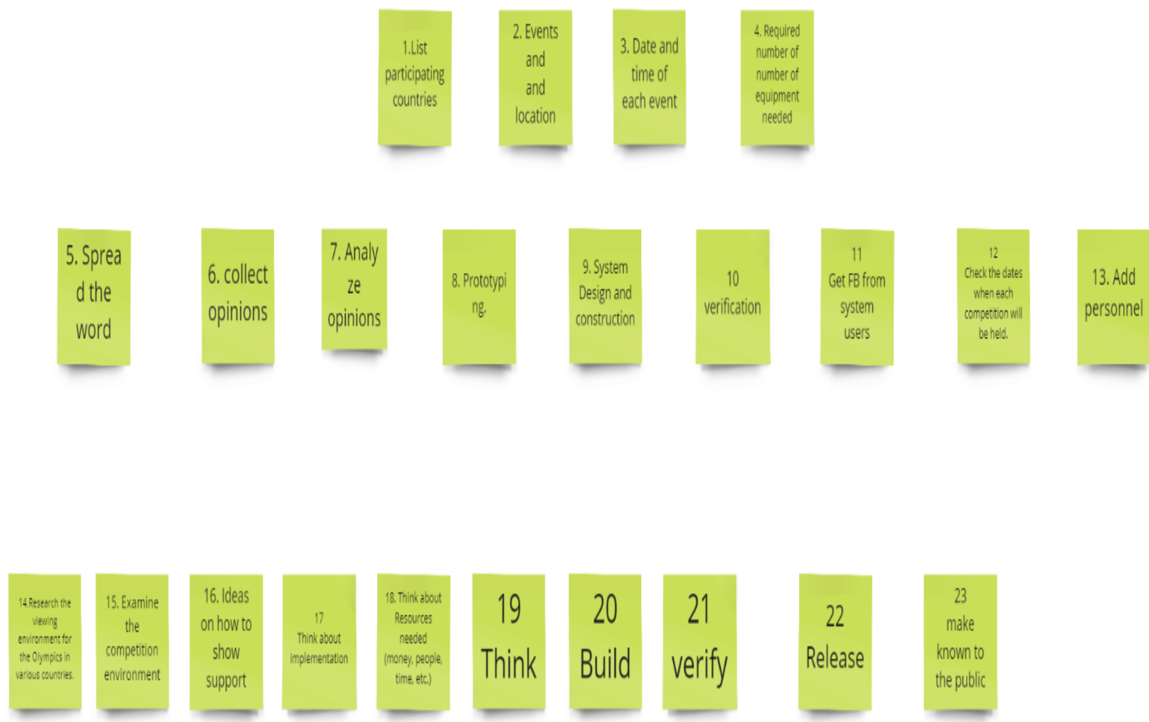


Fig. 16 Step 3 Group B illustration

-***Step4:*** Team members took 20 minutes to discuss with each other why they think the activity they wrote was essential for the task process.

-***Step 5:*** Team members took 5 minutes to select all activities and build a Fuzzy map with the task process as the center of the map.

-***Step 6:*** Team members took 10 minutes to copy the fuzzy map in their individual work space and rated each concept based on their perception of how important each concept is for the task by using the Fuzzy scale provided.

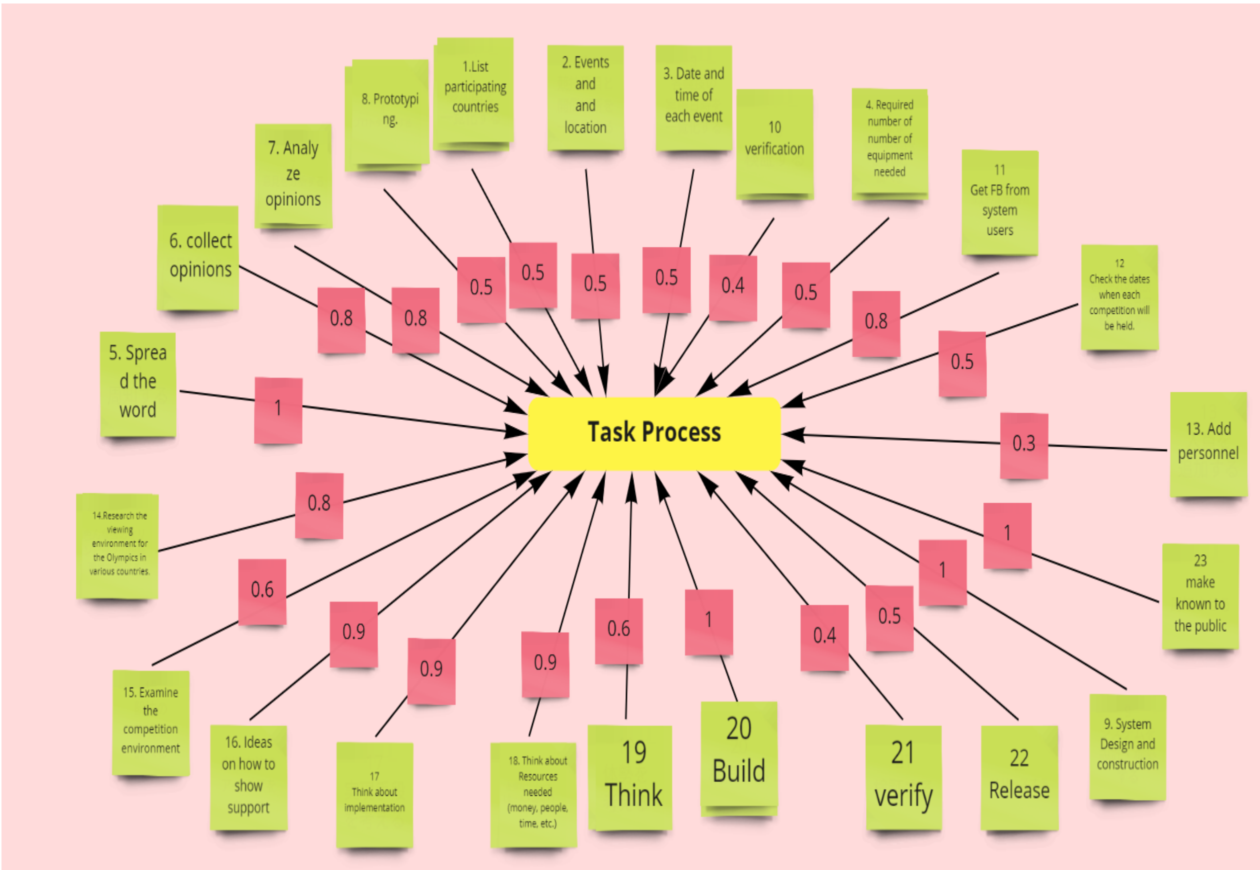


Fig. 17 Step 6 Group B illustration

-***Step 7:*** Team members then answered the survey to gauge how satisfied they were with the discussion and how their opinions were understood by the others.

### 4.2.1. Formulas

**(a) Average Fuzzy Weight**

Sum of all the Fuzzy Weight Values of each concept divided by total number of participants.

Example based on group A, team 1:

$$C1=\left[\frac{Fuzzy\ Weight\ M1+Fuzzy\ Weight\ M2+Fuzzy\ Weight\ M3}{3}\right]$$

$$=\left[\frac{0.7+0.7+0.9}{3}\right]$$

=0.76

**(b)Quartile range calculation:**

Example based on group A, team 1:

(i) List down all the fuzzy weight values scored by each participant for each concept.

0.7,0.7,0.9,1,0.8,0.9,1,1,0.9,0.7,0.4,0.4,1,0.6,1,0.7,0.7,0.5,1,0.7,0.5,1,1,1,1,0.2,0.5

(ii) Arrange the fuzzy weight values from least to greatest (ascending order):

0.2,0.4,0.4,0.5,0.5,0.5,0.6,0.7,0.7,0.7,0.7,0.7,0.7,0.8,0.9,0.9,0.9,1,1,1,1,1,1,1,1,1,1

(iii) Using the basic Quartile range formula, Find Q1, Q2 and Q3. The formula will depend on the list of values, if it's odd or even.
-Since the given fuzzy values are a list of odd sets, the following formula was used.

First find, $Q2=\left[\frac{n+1}{2}\right]$

$=\left[\frac{27+1}{2}\right]$

=14

Therefore the 14th number in the set is Q2.
Q1 is the middle of the lower half of the set and Q3 the middle of the higher half of the set.
Then find Q1 = 0.6
Q3 =1

(iv) Using the formula for interquartile range to find the medium consensus level.

Q2 (Medium Quartile Range) =0.8
Q1(Lower Quartile Range) =0.6
Q3 (Higher Quartile Range) =1

Interquartile range (IQR) = (Q3-Q1)
= (1-0.6)
=0.4

Interquartile Range = Medium Consensus Level = 0.4

**(c) Concepts Consensus Calculation:**

The concept consensus is calculated by subtracting the highest fuzzy weight value from the lowest fuzzy weight value rated from the same concept.
Example based on group A, team 1:

C1= $(Highest\ Fuzzy\ Weight\ Value\ -\ Lowest\ Fuzzy\ Weight\ Value)$
=0.9-0.7
=0.2

### 4.2.2. Group evaluation

**(a) Group A**

After conducting a number of experiments, data were archived. Calculations were done based on the formulas mentioned above.
Following tables show the results of all the data and calculations made from those data. Detailed calculation is in annexure I

Table 5. Group A Team 1 results

| **Concept No.** | **Fuzzy Weight** | | | **Average Fuzzy Weight** | **Consensus Score (Medium Level=0.4)** | **Consensus Level** |
|---|---|---|---|---|---|---|
| | **Member 1** | **Member 2** | **Member 3** | | | |
| **C1** | **0.7** | **0.7** | **0.9** | **0.76** | **0.2** | **High** |
| **C2** | **1** | **0.8** | **0.9** | **0.9** | **0.2** | **High** |
| **C3** | **1** | **1** | **0.9** | **0.96** | **0.1** | **High** |
| **C4** | **0.7** | **0.4** | **0.4** | **0.5** | **0.3** | **High** |
| **C5** | **1** | **0.6** | **1** | **0.86** | **0.4** | **Medium** |
| **C6** | **0.7** | **0.7** | **0.5** | **0.63** | **0.2** | **High** |
| **C7** | **1** | **0.7** | **0.5** | **0.73** | **0.5** | **Low** |
| **C8** | **1** | **1** | **1** | **1** | **0** | **High** |
| **C9** | **1** | **0.2** | **0.5** | **0.56** | **0.8** | **Low** |

The above table shows the final result based on the previous calculations done for Group A team 1.

Below is the brief description of the table result:

-The team consisted of three members and they came up with a total of 9 concepts. Each member scored each concept as shown in the table.

-By using the fuzzy weight values given by each member we calculated the average fuzzy weight for each concept.
-Inter quartile range formula is used to find the medium consensus level which is 0.4.
- For each concept the consensus score is calculated by subtracting the highest fuzzy value to the lowest fuzzy value rated by each member.

- Conditions:
High level consensus: <0.4
Medium level consensus: =0.4
Low level consensus: >0.4

**Conclusion**

All the concepts have scored average fuzzy weight values above or equal to 0.5 which means that all members perceive all the concepts as important for their task process. Out of the 9 concepts C1, C2, C3, C4, C6 and C8 have scored less than 0.4(medium consensus level) which are all considered to have high levels of consensus. Concept C5 exactly scored 0.4 which is considered to have medium level of consensus. Concepts C7 and C9 have scored above 0.4(medium consensus level) which are considered to have low levels of consensus. Therefore, Group A, team 1 has overall 66.6% of consensus.

Table 6. Group A Team 2 results

| Concept No. | Fuzzy Weight | | | Average Fuzzy Weight | Consensus Score (Medium Level=0.6) | Consensus Level |
|---|---|---|---|---|---|---|
| | Member 1 | Member 2 | Member 3 | | | |
| C1 | 1 | 0.85 | 1 | 0.95 | 0.15 | High |
| C2 | 1 | 0.9 | 1 | 0.96 | 0.1 | High |
| C3 | 1 | 1 | 1 | 1 | 0 | High |
| C4 | 1 | 1 | 0.4 | 0.8 | 0.6 | Medium |
| C5 | 0.2 | 0.2 | 0.25 | 0.21 | 0.05 | High |
| C6 | 1 | 0.85 | 0.4 | 0.75 | 0.6 | Medium |
| C7 | 0.4 | 0 | 0.25 | 0.21 | 0.15 | High |
| C8 | 0.2 | 0.5 | 0 | 0.23 | 0.5 | High |
| C9 | 0.3 | 0.85 | 0.25 | 0.46 | 0.6 | Medium |
| C10 | 0.4 | 0.5 | 0.25 | 0.38 | 0.25 | High |
| C11 | 0.6 | 1 | 1 | 0.86 | 0.4 | High |
| C12 | 0.9 | 0.85 | 0.75 | 0.83 | 0.15 | High |
| C13 | 0.5 | 0.5 | 1 | 0.66 | 0.5 | High |
| C14 | 1 | 0.85 | 1 | 0.95 | 0.15 | High |

The above table shows the final result based on the previous calculations done for Group A, team 1.

2.Below is the brief description of the table result:

-The team consisted of three members and they came up with a total of 14 concepts. Each member scored each concept as shown in the table.
-By using the fuzzy weight values given by each member we calculated the average fuzzy weight for each concept.
-Inter quartile range formula is used to find the medium consensus level which is 0.6.
- For each concept the consensus score is calculated by subtracting the highest fuzzy value to the lowest fuzzy value rated by each member.
- Conditions:
High level consensus: <0.6
Medium level consensus: =0.6
Low level consensus: >0.6

**Conclusion**
All the concepts have scored average fuzzy weight values above 0.5 which means that all members perceive all the concepts as important for their task process, except concept C5, C7, C8, C9 and C10 which scored below 0.5. Out of the 14 concepts C1, C2, C3, C5, C7, C8, C10, C11, C12, C13 and C14 have scored less than 0.6(medium consensus level) which are all considered to have high levels of consensus. Concept C4, C6 and C9 scored exactly 0.6 which is considered to have medium level of consensus. There was no consensus value above 0.6, which means 0% dissensus.
Therefore, Group A, team 2 has overall 78.57% of consensus.

Table 7. Group A Team 3 results

| Concept No. | Fuzzy Weight | | | Average Fuzzy Weight | Consensus Score (Medium Level=0.4) | Consensus Level |
|---|---|---|---|---|---|---|
| | Member 1 | Member 2 | Member 3 | | | |
| C1 | 0.75 | 1 | 0.8 | 0.85 | 0.25 | High |
| C2 | 1 | 0.5 | 0.4 | 0.63 | 0.6 | Low |
| C3 | 0.75 | 0.3 | 0.3 | 0.45 | 0.45 | Low |
| C4 | 0.7 | 0.1 | 0.8 | 0.53 | 0.7 | Low |
| C5 | 0.9 | 1 | 0.8 | 0.9 | 0.2 | High |
| C6 | 0.7 | 0.3 | 0.1 | 0.37 | 0.6 | Low |
| C7 | 1 | 1 | 0.8 | 0.93 | 0.2 | High |
| C8 | 0.75 | 0.5 | 0.6 | 0.62 | 0.25 | High |
| C9 | 0.6 | 1 | 0.8 | 0.8 | 0.4 | Medium |
| C10 | 0.6 | 1 | 0.7 | 0.77 | 0.4 | Medium |
| C11 | 0.75 | 1 | 1 | 0.92 | 0.25 | High |
| C12 | 1 | 1 | 0.6 | 0.87 | 0.4 | Medium |
| C13 | 0.9 | 0.1 | 0.6 | 0.53 | 0.8 | Low |
| C14 | 0.75 | 0.1 | 0.2 | 0.35 | 0.65 | Low |
| C15 | 0.85 | 0.1 | 0.3 | 0.42 | 0.75 | Low |
| C16 | 0.9 | 0.1 | 0.6 | 0.53 | 0.8 | Low |
| C17 | 0.9 | 0.1 | 1 | 0.67 | 0.8 | Low |

| | | | | | | |
|---|---|---|---|---|---|---|
| **C18** | **0.75** | **0.7** | **0.7** | **0.72** | **0.05** | **High** |

The above table shows the final result based on the previous calculations done for Group A, team 3.

Below is the brief description of the table result:

-The team consisted of three members and they came up with a total of 18 concepts. Each member scored each concept as shown in the table.
-By using the fuzzy weight values given by each member we calculated the average fuzzy weight for each concept.
-Inter quartile range formula is used to find the medium consensus level which is 0.4.
- For each concept the consensus score is calculated by subtracting the highest fuzzy value to the lowest fuzzy value rated by each member.
- Conditions:
High level consensus: <0.4
Medium level consensus: =0.4
Low level consensus: >0.4

**Conclusion**

All the concepts have scored average fuzzy weight values above 0.5 which means that all members perceive all the concepts as important for their task process, except concept C3, C6, C14 and C15 which scored below 0.5. Out of the 18 concepts
C1, C5, C7, C8, C11 and C18 have scored less than 0.4(medium consensus level) which are all considered to have high levels of consensus. Concept C9, C10 and C12 scored exactly 0.4 which is considered to have medium level of consensus. Concepts C2, C3, C4, C6, C13, C14, C15, C16 and C17 have scored above 0.4(medium consensus level) which are considered to have low levels of consensus. Therefore, Group A, team 3 has overall 33.3% of consensus.

Table 8. Group A Team 4 results

| Concept No. | Fuzzy Weight | | | Average Fuzzy Weight | Consensus Score (Medium Level=0.3 | Consensus Level |
|---|---|---|---|---|---|---|
| | Member 1 | Member 2 | Member 3 | | | |
| C1 | 1 | 1 | 1 | 1 | 0 | High |
| C2 | 0.8 | 0.8 | 1 | 0.86 | 0.2 | High |
| C3 | 0.9 | 1 | 1 | 0.96 | 0.1 | High |
| C4 | 1 | 0.8 | 1 | 0.93 | 0.2 | High |
| C5 | 1 | 0.8 | 1 | 0.93 | 0.2 | High |
| C6 | 1 | 0.8 | 1 | 0.93 | 0.2 | High |
| C7 | 1 | 0.8 | 1 | 0.93 | 0.2 | High |
| C8 | 1 | 0.8 | 1 | 0.93 | 0.2 | High |
| C9 | 1 | 0.8 | 0.8 | 0.86 | 0.2 | High |
| C10 | 0.6 | 0.8 | 0.5 | 0.63 | 0.3 | Medium |
| C11 | 0.45 | 0.7 | 0.5 | 0.55 | 0.25 | High |
| C12 | 0.9 | 0.8 | 1 | 0.9 | 0.2 | High |
| C13 | 0.45 | 0.8 | 1 | 0.75 | 0.55 | Low |
| C14 | 0.8 | 0.8 | 1 | 0.86 | 0.2 | High |
| C15 | 0.4 | 0.8 | 0.5 | 0.56 | 0.4 | Low |
| C16 | 0.4 | 0.7 | 0.5 | 0.53 | 0.3 | Medium |
| C17 | 0.5 | 0.7 | 0.5 | 0.56 | 0.2 | High |

| | | | | | | |
|---|---|---|---|---|---|---|
| **C18** | **0.5** | **0.7** | **0.7** | **0.63** | **0.2** | **High** |

The above table shows the final result based on the previous calculations done for Group A, team 4. Below is the brief description of the table result:

-The team consisted of three members and they came up with a total of 18 concepts. Each member scored each concept as shown in the table.
-By using the fuzzy weight values given by each member we calculated the average fuzzy weight for each concept.
-Inter quartile range formula is used to find the medium consensus level which is 0.3.
- For each concept the consensus score is calculated by subtracting the highest fuzzy value to the lowest fuzzy value rated by each member.
- Conditions:
High level consensus: <0.3
Medium level consensus: =0.3
Low level consensus: >0.3

**Conclusion**

All the concepts have scored average fuzzy weight values above 0.5 which means that all members perceive all the concepts as important for their task process. Out of the 18 concepts C1, C2, C3, C4, C5, C6, C7, C8, C9, C11, C12, C14, C17 and C18 have scored less than 0.3(medium consensus level) which are all considered to have high levels of consensus. Concept C10 and C16 scored exactly 0.3 which is considered to have medium level of consensus. Concepts C13 and C15 have scored above 0.3(medium consensus level) which are considered to have low levels of consensus.
Therefore, Group A, team 4 has overall 77.7% of consensus.

**(b)Group B**

Table 9. Group B Team 1 results

| Concept No. | Fuzzy Weight | | | Average Fuzzy Weight | Consensus Score (Medium Level=0.5) | Consensus Level |
|---|---|---|---|---|---|---|
| | Member 1 | Member 2 | Member 3 | | | |
| C1 | 1 | 0.5 | 0.2 | 0.56 | 0.8 | Low |
| C2 | 1 | 0.5 | 0.1 | 0.53 | 0.9 | Low |
| C3 | 1 | 0.5 | 0.1 | 0.53 | 0.9 | Low |
| C4 | 1 | 0.4 | 1 | 0.8 | 0.6 | Low |
| C5 | 1 | 0.5 | 0.1 | 0.53 | 0.9 | Low |
| C6 | 0.4 | 0.8 | 0.8 | 0.66 | 0.4 | High |
| C7 | 1 | 0.5 | 0.2 | 0.56 | 0.8 | Low |
| C8 | 0.7 | 0.3 | 0.8 | 0.6 | 0.5 | Medium |
| C9 | 0.8 | 1 | 1 | 0.93 | 0.2 | High |
| C10 | 1 | 1 | 0.8 | 0.93 | 0.2 | High |
| C11 | 1 | 0.5 | 1 | 0.83 | 0.5 | Medium |
| C12 | 1 | 0.4 | 1 | 0.8 | 0.6 | Low |
| C13 | 1 | 1 | 0.7 | 0.9 | 0.3 | High |
| C14 | 1 | 0.6 | 0.4 | 0.66 | 0.6 | Low |
| C15 | 0.8 | 0.9 | 0.7 | 0.8 | 0.2 | High |

| | | | | | | |
|---|---|---|---|---|---|---|
| **C16** | **1** | **0.9** | **1** | **0.96** | **0.1** | **High** |
| **C17** | **0.8** | **0.9** | **1** | **0.9** | **0.2** | **High** |
| **C18** | **0.9** | **0.6** | **0.3** | **0.6** | **0.6** | **Low** |
| **C19** | **0.7** | **0.8** | **0.7** | **0.73** | **0.1** | **High** |
| **C20** | **0.8** | **1** | **1** | **0.93** | **0.2** | **High** |
| **C21** | **0.7** | **0.8** | **0.7** | **0.73** | **0.1** | **High** |
| **C22** | **0.7** | **0.8** | **1** | **0.83** | **0.3** | **High** |
| **C23** | **0.7** | **0.5** | **0.7** | **0.63** | **0.2** | **High** |

The above table shows the final result based on the previous calculations done for GroupB,Team 1.Below is the brief description of the table result:

-The team consisted of three members and they came up with a total of 23 concepts. Each member scored each concept as shown in the table.
-By using the fuzzy weight values given by each member we calculated the average fuzzy weight for each concept.
-Inter quartile range formula is used to find the medium consensus level which is 0.5.
- For each concept the consensus score is calculated by subtracting the highest fuzzy value to the lowest fuzzy value rated by each member.
- Conditions:
High level consensus: <0.5
Medium level consensus: =0.5
Low level consensus: >0.5

**Conclusion**

All the concepts have scored average fuzzy weight values above or equal to 0.5 which means that all members perceive all the concepts as important for their task process. Out of the 23 concepts C6, C9, C10, C13, C15, C16, C17, C19, C20, C21, C22, C23 and C8 have scored less than 0.5(medium consensus level) which are all considered to have high levels of consensus. Concept C8 and C11 scored exactly 0.5 which is considered to have medium level of consensus.

Concepts C1, C2, C3, C4, C5, C7, C12, C14 and C17 have scored above 0.5 (medium consensus level) which are considered to have low levels of consensus. Therefore, Group B, team 1 has overall 52.17% of consensus.

Table 10. Group B Team 2 results

| Concept No. | Fuzzy Weight | | | Average Fuzzy Weight | Consensus Score (Medium Level=0.39) | Consensus Level |
|---|---|---|---|---|---|---|
| | Member 1 | Member 2 | Member 3 | | | |
| C1 | 1 | 0.5 | 1 | 0.83 | 0.5 | Low |
| C2 | 0.5 | 0.5 | 0.8 | 0.6 | 0.3 | High |
| C3 | 0.3 | 0.1 | 0.5 | 0.3 | 0.4 | Low |
| C4 | 0.7 | 0.2 | 0.8 | 0.56 | 0.6 | Low |
| C5 | 0.7 | 0.8 | 0.5 | 0.66 | 0.3 | High |
| C6 | 1 | 0.8 | 0.8 | 0.86 | 0.2 | High |
| C7 | 0.7 | 0.2 | 0.8 | 0.56 | 0.6 | Low |
| C8 | 1 | 0.8 | 0.8 | 0.86 | 0.2 | High |
| C9 | 1 | 0.75 | 1 | 0.91 | 0.25 | High |
| C10 | 1 | 1 | 1 | 1 | 0 | High |
| C11 | 1 | 0.9 | 0.8 | 0.9 | 0.2 | High |
| C12 | 0.89 | 0.5 | 0.7 | 0.69 | 0.39 | Medium |
| C13 | 0.89 | 0.2 | 0.8 | 0.63 | 0.69 | Low |
| C14 | 0.89 | 0.5 | 0.7 | 0.69 | 0.39 | Medium |
| C15 | 0.89 | 0.2 | 0.8 | 0.63 | 0.69 | Low |

| | | | | | | |
|---|---|---|---|---|---|---|
| **C16** | **0.89** | **0.5** | **1** | **0.79** | **0.5** | **Low** |
| **C17** | **0.89** | **0.5** | **0.7** | **0.69** | **0.39** | **Medium** |
| **C18** | **0.89** | **0.5** | **1** | **0.79** | **0.5** | **Low** |
| **C19** | **1** | **0.5** | **1** | **0.83** | **0.5** | **Low** |
| **C20** | **0.89** | **0.5** | **1** | **0.79** | **0.5** | **Low** |
| **C21** | **0.89** | **0.1** | **1** | **0.63** | **0.9** | **Low** |
| **C22** | **0.74** | **0.3** | **0.5** | **0.51** | **0.44** | **Low** |
| **C23** | **0.74** | **0.3** | **0.5** | **0.51** | **0.44** | **Low** |
| **C24** | **0.89** | **0.3** | **0.5** | **0.56** | **0.59** | **Low** |
| **C25** | **0.89** | **0.5** | **0.5** | **0.63** | **0.39** | **Medium** |
| **C26** | **0.89** | **0.5** | **0.5** | **0.63** | **0.39** | **Medium** |
| **C27** | **0.89** | **0.8** | **0.5** | **0.73** | **0.39** | **Medium** |
| **C28** | **0.89** | **0.7** | **0.5** | **0.69** | **0.39** | **Medium** |
| **C29** | **0.5** | **0.7** | **1** | **0.73** | **0.5** | **Low** |
| **C30** | **1** | **0.8** | **1** | **0.93** | **0.2** | **High** |
| **C31** | **1** | **0.5** | **1** | **0.83** | **0.5** | **Low** |
| **C32** | **0.5** | **0.25** | **1** | **0.58** | **0.5** | **Low** |

The above table shows the final result based on the previous calculations done for Group B, team 2. Below is the brief description of the table result:

-The team consisted of three members and they came up with a total of 32 concepts. Each member scored each concept as shown in the table.
-By using the fuzzy weight values given by each member we calculated the average fuzzy weight for each concept.
-Inter quartile range formula is used to find the medium consensus level which is 0.39.
- For each concept the consensus score is calculated by subtracting the highest fuzzy value to the lowest fuzzy value rated by each member.
- Conditions:
High level consensus: <0.39
Medium level consensus: =0.39
Low level consensus: >0.39

**Conclusion**
All the concepts have scored average fuzzy weight values above 0.5 which means that all members perceive all the concepts as important for their task process, except concept C3 which scored below 0.5. Out of 32 concepts C2, C5, C6, C8, C9, C10, C11 and C30 have scored less than 0.5 (medium consensus level) which are all considered to have high levels of consensus. Concept C12, C14, C17, C25, C26, C27, C28 scored exactly 0.39 which is considered to have medium level of consensus. Concepts C1, C3, C4, C7, C13, C15, C16, C18, C19, C20, C21, C22, C23, C24, C29, C31 and C32 have scored above 0.0.39 (medium consensus level) which are considered to have low levels of consensus. Therefore, Group B, team 2 has overall 25% of consensus.

Table 11. Group B Team 3 results

| Concept No. | Fuzzy Weight | | | Average Fuzzy Weight | Consensus Score (Medium Level=0.5) | Consensus Level |
|---|---|---|---|---|---|---|
| | Member 1 | Member 2 | Member 3 | | | |
| C1 | 1 | 1 | 1 | 1 | 0 | High |
| C2 | 0.5 | 1 | 0.2 | 0.56 | 0.8 | Low |
| C3 | 0.75 | 1 | 1 | 0.91 | 0.25 | High |
| C4 | 0.5 | 1 | 1 | 0.83 | 0.5 | Medium |
| C5 | 0.75 | 1 | 0.5 | 0.75 | 0.5 | Medium |
| C6 | 1 | 1 | 0.5 | 0.83 | 0.5 | Medium |
| C7 | 1 | 1 | 0.5 | 0.83 | 0.5 | Medium |
| C8 | 1 | 1 | 0.5 | 0.83 | 0.5 | Medium |
| C9 | 0.5 | 1 | 0.5 | 0.66 | 0.5 | Medium |
| C10 | 1 | 1 | 0.25 | 0.75 | 0.75 | Low |
| C11 | 0.25 | 1 | 0.25 | 0.5 | 0.75 | Low |
| C12 | 1 | 1 | 0.25 | 0.75 | 0.75 | Low |
| C13 | 0.1 | 1 | 0.25 | 0.45 | 0.9 | Low |
| C14 | 1 | 1 | 1 | 1 | 0 | High |
| C15 | 1 | 1 | 0.5 | 0.83 | 0.5 | High |
| C16 | 1 | 1 | 0.5 | 0.83 | 0.5 | High |
| C17 | 0.25 | 0.8 | 0.25 | 0.43 | 0.55 | Low |

| | | | | | | |
|---|---|---|---|---|---|---|
| **C18** | **0.75** | **0.8** | **0.5** | **0.68** | **0.3** | **High** |
| **C19** | **0.25** | **1** | **0.25** | **0.5** | **0.75** | **Low** |

The above table shows the final result based on the previous calculations done for Group B,Team 3.Below is the brief description of the table result:

-The team consisted of three members and they came up with a total of 19 concepts. Each member scored each concept as shown in the table.
-By using the fuzzy weight values given by each member we calculated the average fuzzy weight for each concept.
-Inter quartile range formula is used to find the medium consensus level which is 0.5.
- For each concept the consensus score is calculated by subtracting the highest fuzzy value to the lowest fuzzy value rated by each member.
- Conditions:
High level consensus: <0.5
Medium level consensus: =0.5
Low level consensus: >0.5

**Conclusion**
All the concepts have scored average fuzzy weight values above 0.5 which means that all members perceive all the concepts as important for their task process, except concepts C13 and C17 which scored below 0.5. Out of the 19 concepts C1, C3, C14, C15, C16 and C18 have scored less than 0.5(medium consensus level) which are all considered to have high levels of consensus. Concept C4, C5, C6, C7 .C8, C9 exactly 0.5 which is considered to have medium level of consensus. Concepts C2, C10, C11, C12, C13, C17 and C19 have scored above 0.5(medium consensus level) which are considered to have low levels of consensus. Therefore, Group B, team 3 has overall 31.5% of consensus

Table 12. Group B Team 4 results

| Concept No. | Fuzzy Weight | | | Average Fuzzy Weight | Consensus Score (Medium Level=0.2) | Consensus Level |
|---|---|---|---|---|---|---|
| | Member 1 | Member 2 | Member 3 | | | |
| C1 | 1 | 0.5 | 0.2 | 0.56 | 0.8 | Low |
| C2 | 1 | 1 | 1 | 1 | 0 | High |
| C3 | 0.8 | 1 | 1 | 0.93 | 0.2 | Medium |
| C4 | 1 | 1 | 1 | 1 | 0 | High |
| C5 | 1 | 1 | 0.8 | 0.93 | 0.2 | High |
| C6 | 1 | 0.5 | 0.8 | 0.76 | 0.5 | Low |
| C7 | 1 | 0.7 | 1 | 0.9 | 0.3 | Low |
| C8 | 0.8 | 1 | 0.5 | 0.76 | 0.5 | Low |
| C9 | 0.8 | 1 | 1 | 0.93 | 0.2 | Medium |
| C10 | 0.8 | 1 | 1 | 0.93 | 0.2 | Medium |
| C11 | 0.8 | 1 | 1 | 0.93 | 0.2 | Medium |
| C12 | 0.8 | 1 | 0.8 | 0.86 | 0.2 | Medium |
| C13 | 1 | 1 | 0.5 | 0.83 | 0.5 | Low |
| C14 | 1 | 1 | 1 | 1 | 0 | High |

The above table shows the final result based on the previous calculations done for Group Team 4. Below is the brief description of the table result:

-The team consisted of three members and they came up with a total of 14 concepts. Each member scored each concept as shown in the table.
-By using the fuzzy weight values given by each member we calculated the average fuzzy weight for each concept.
-Inter quartile range formula is used to find the medium consensus level which is 0.2.
- For each concept the consensus score is calculated by subtracting the highest fuzzy value to the lowest fuzzy value rated by each member.
- Conditions:
High level consensus: <0.2
Medium level consensus: =0.2
Low level consensus: >0.2

**Conclusion**

All the concepts have scored average fuzzy weight values above 0.2 which means that all members perceive all the concepts as important for their task process, except concept C1 which scored below 0.5. Out of the 14 concepts C2, C4, C5 and C14 have scored less than 0.2(medium consensus level) which are all considered to have high levels of consensus. Concept C9, C10, C11, C12 have scored exactly 0.2 which is considered to have medium level of consensus. Concepts C1, C6, C7, C8 and C13 have scored above 0.2(medium consensus level) which are considered to have low levels of consensus. Therefore, Group B, team 4 has overall 28.5% of consensus.

### 4.2.3 Verification result analysis

**(a) Verification criteria**

The verification for the experiment was done based on the following criteria:

Criteria 1: Teams in group A should achieve an overall high consensus level percentage above 50% while using each process compared to Group B.
Criteria 2: At least half of total teams in Group A should have a high consensus level above 50% compared to teams in Group B.

**Criteria 1:** In order to verify criteria 1, the consensus level percentage tables were obtained for Group A and Group B. The table consists of five rows and five columns. First column represents the teams, the second column represents the total numbers of concepts each team came up with and the rest of the column represents the percentage of consensus from high, medium and low.

*Consensus percentage calculation:*

- High Consensus Percentage (H.C.P): it was calculated by dividing numbers of concepts that have a high level of consensus to total number of concepts and multiplying the value with hundred.
  H.C.P = (No. of concept with high consensus/total no. of concept) x100
  Example based on Group A, team1
  = (6/9) *100
  = 66.6%

- Medium Consensus Percentage (M.C.P):it was calculated by dividing numbers of concepts that have a medium level of consensus to total number of concepts and multiplying the value with hundred.
  M.C.P = (No. of concept with medium consensus/total no. of concept) x100
  Example based on Group A, team1
  = (1/9) *100
  = 11.1%
- Low Consensus Percentage (L.C.P): it was calculated by dividing numbers of concepts that have a Low level of consensus to total number of concepts and multiplying the value with hundred.
  L.C.P = (No. of concept with Low consensus/total no. of concept) x100
  Example based on Group A, team1
  = (2/9) *100
  = 22.2%

*Expected Result:*
Teams in Group A, are expected to have a high-level consensus percentage compared to teams in Group B.

**Criteria 2:** In order to verify criteria 2, the results table from criteria 1 needs to be checked.

*Expected Result:*
At least half of the total teams in Group A are expected to have a high-level consensus percentage compared to teams in Group B.

**(b) Consensus percentage result**

Based on the results obtained from the calculation, the following conclusion are drawn:

Table 13. Group A Consensus Percentage results

| | Group A | | | |
|---|---|---|---|---|
| | **Total Number of Concepts** | **High Consensus percentage (%)** | **Medium Consensus Percentage (%)** | **Low Consensus Percentage (%)** |
| **Team 1** | 9 | 66.6% | 11.11% | 22.2% |
| **Team 2** | 14 | 78.57% | 21.4% | 0% |
| **Team 3** | 18 | 33.3% | 16.6% | 50% |
| **Team 4** | 18 | 77.7% | 11.11% | 11.115% |

- Team 1 after sharing knowledge with each other were on a high level of consensus as they had the opportunity to interpret each other's knowledge, as well as clarifying their misinterpretation. Therefore, Team 1 was able to achieve a high level of consensus of 66.6% which shows that team members were successful in developing a high level of cognitive consensus about most of the knowledge shared within the team.

- Team 2 after sharing knowledge with each other were on a high level of consensus as they had the opportunity to interpret each other's knowledge, as well as clarifying their misinterpretation. Therefore, Team 2 was able to achieve a high level of consensus of 78.57% which shows that team members were successful in developing high level of cognitive consensus about most of the knowledge shared within the team.

- Team 4 after sharing knowledge with each other were on a high level of consensus as they had the opportunity to interpret each other's knowledge, as well as clarifying their misinterpretation. Therefore, Team 4 was able to achieve a high level of consensus of 77.7% which shows that team members were successful in developing high level of cognitive consensus about most of the knowledge shared within the team.

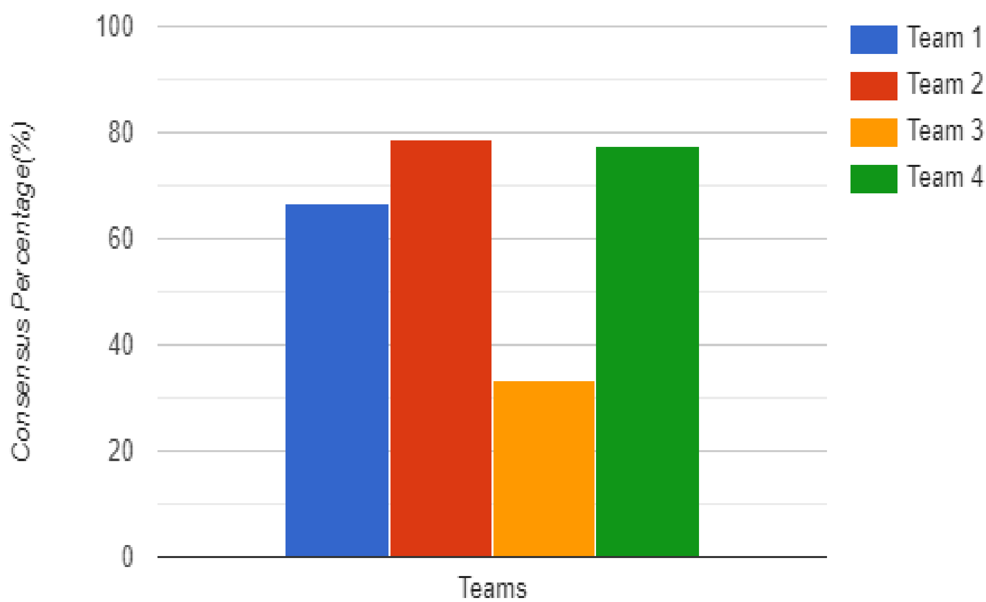


Fig 17. Group A - High consensus percentage level graph

Table 14. Group B Consensus Percentage results

| | Group B | | | |
|---|---|---|---|---|
| | **Total Number of Concepts** | **High Consensus percentage (%)** | **Medium Consensus Percentage (%)** | **Low Consensus Percentage (%)** |
| **Team 1** | 23 | 52.17% | 8.6% | 39.13% |
| **Team 2** | 32 | 25% | 21.87% | 53.12% |
| **Team 3** | 19 | 31.5% | 31.5% | 36.8% |
| **Team 4** | 14 | 28.5% | 35.7% | 35.7% |

- Team 1 after sharing knowledge with each other were on a high level of consensus as they had the opportunity to share knowledge with each other and explain the reason why their knowledge is valuable to that task process, by using the traditional method of knowledge sharing virtually. However, Team 1 was able to achieve a level of consensus of 52.17% which shows that team members were successful in developing a high level of cognitive consensus about most of the knowledge shared within the team.

- On the other hand, team 2 after sharing knowledge with each other were on a low level of consensus even though they had the opportunity to share knowledge with each other and explain the reason why their knowledge is valuable to that task process, by using the traditional method of knowledge sharing virtually. Thus, Team 2 was just able to achieve a level of consensus of 25% which shows that team members were unsuccessful in developing a high level of cognitive consensus about most of the knowledge shared within the team.

- Furthermore, team 3 after sharing knowledge with each other were on a low level of consensus even though they had the opportunity to share knowledge with each other and explain the reason why their knowledge is valuable to that task process, by using the traditional method of knowledge sharing virtually. Thus, Team 3 was just able to achieve a level of consensus of 31.5% which shows that team members were unsuccessful in developing a high level of cognitive consensus about most of the knowledge shared within the team.

- Finally, team 4 after sharing knowledge with each other were on a low level of consensus even though they had the opportunity to share knowledge with each other and explain the reason why their knowledge is valuable to that task process, by using the traditional method of knowledge sharing virtually. Thus, Team 4 was just able to achieve a level of consensus of 28.5% which shows that team members were unsuccessful in developing a high level of cognitive consensus about most of the knowledge shared within the team.

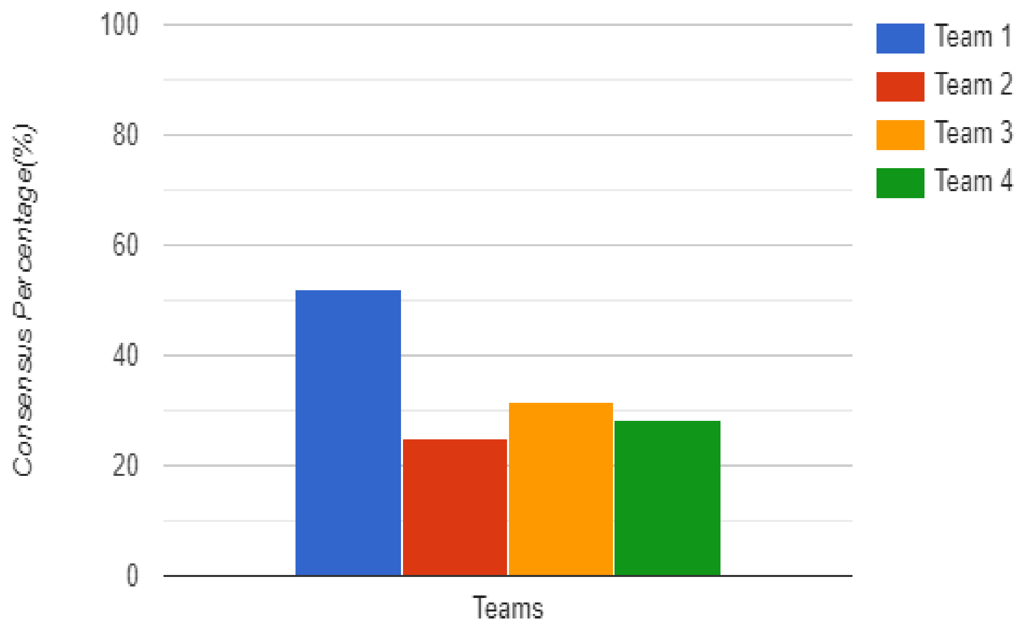


Fig 18. Group B - High consensus percentage level graph

Table 15. Criteria 1 Fulfillment (Group A)

| | Criteria 1 |
|---|---|
| Team 1 | ● |
| Team 2 | ● |
| Team 3 | ● |
| Team 4 | ● |

Team 1, Team 2 and Team 4 were able to score 66.6%, 78.57% and 77.7% which are all relatively above 50% of high consensus level which shows that these teams were engaged in significantly high levels of cognitive consensus while sharing knowledge using the proposed process, hence fulfilling the criteria 1.

Table 16. Criteria 1 Fulfillment (Group B)

| | Criteria 1 |
|---|---|
| Team 1 | ● |
| Team 2 | ● |
| Team 3 | ● |
| Team 4 | ● |

Only Team 1 was able to score 52.17% which is just above 50% of high consensus level which shows that only team 1 was engaged in high levels of cognitive consensus while sharing knowledge using the proposed process, hence fulfilling the criteria 1.

Table 17. Criteria 2 Fulfillment (Group A and B)

| Group A | Group B |
|---|---|
| ● | ● |

3 Teams out of 4 teams in Group A have achieved more than 50% of high level of consensus compared to Group B, in which only 1 Team has achieved more than 50% of high level of consensus while sharing knowledge using the proposed process, hence fulfilling the criteria 2.

## 4.3. Validation

An early version of IEEE-012, edition 984, defines validation as "*the process of evaluating a system or component during or at the end of the development process whether it satisfies a specified requirement*". For this process validation criteria were created to ensure that the proposed process works as intended as well as to compare the performance of each process used by both teams.

### 4.3.1. Validation criteria

The validation for the experiment was done based on the following criteria:

Criteria 1: Group A should achieve more than 50 % of positive response for work satisfaction level after using the process compared to Group B.
Criteria 2: Group A should achieve more than 50 % of positive response for how his/her opinion was understood while using the proposed process compared to Group B.

**Criteria 1:** In order to validate criteria 3 a survey was conducted by using Google Forms and at the end of each experiment in which team members from each group had to rate how satisfied they were while using the proposed process to share knowledge during virtual collaboration. Questions such as "How satisfied are you with the discussions?" were asked to each team member in the survey. Likert scale was used to assess team member satisfaction in which the rate varied from Very dissatisfied, Dissatisfied, Okay, Satisfied, and Very Satisfied.

*Expected Result:*
Higher percentage of members from teams in Group A would have a higher level of satisfaction compared to those of Group B.

**Criteria 2:** In order to validate criteria 4 a survey was conducted by using Google Forms and at the end of each experiment in which team members from each group had to rate how sure they were about other members understanding their shared ideas while using the proposed process to share knowledge during virtual collaboration. Questions such as "How far do you think your idea was understood by others?" were asked to each team member in the survey. Likert scale was used to assess team member perception about others understanding their shared ideas in which the rate varied from None of my opinions, Few of my opinions, Half of my opinions, Most of my opinions, and All of my opinions.

*Expected Result:*
Higher percentage of members from teams in Group A would have a level of perception about others understanding their ideas compared to those of Group B.

### 4.3.2. Survey Results

*Group A:*

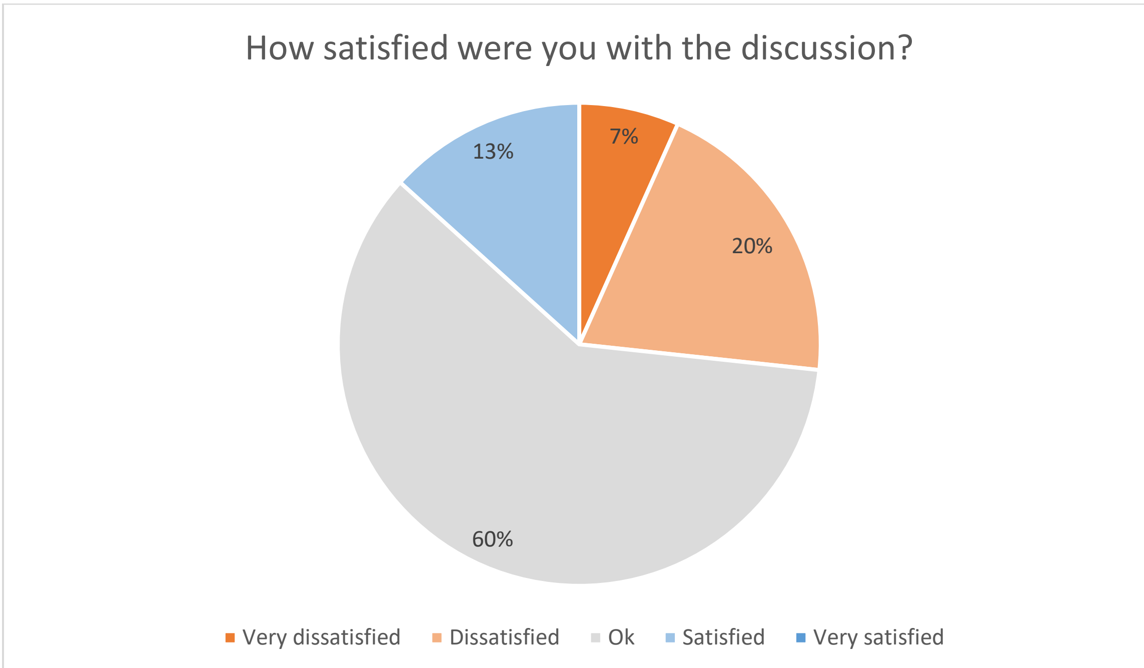


Fig 19. Group A Satisfaction Level

The above pie chart represents the survey result for the question *"How satisfied are you with the discussion?*". For member belonging to Group A response in the survey is as following:

- 60% of the members were *ok* with the discussion while using the proposed process.
- 13.3% of the members were *satisfied* with the discussion while using the proposed process.
- 20% of the members were *dissatisfied* with the discussion while using the process.
- 6.7% of members were very *dissatisfied* with the discussion while using the process.

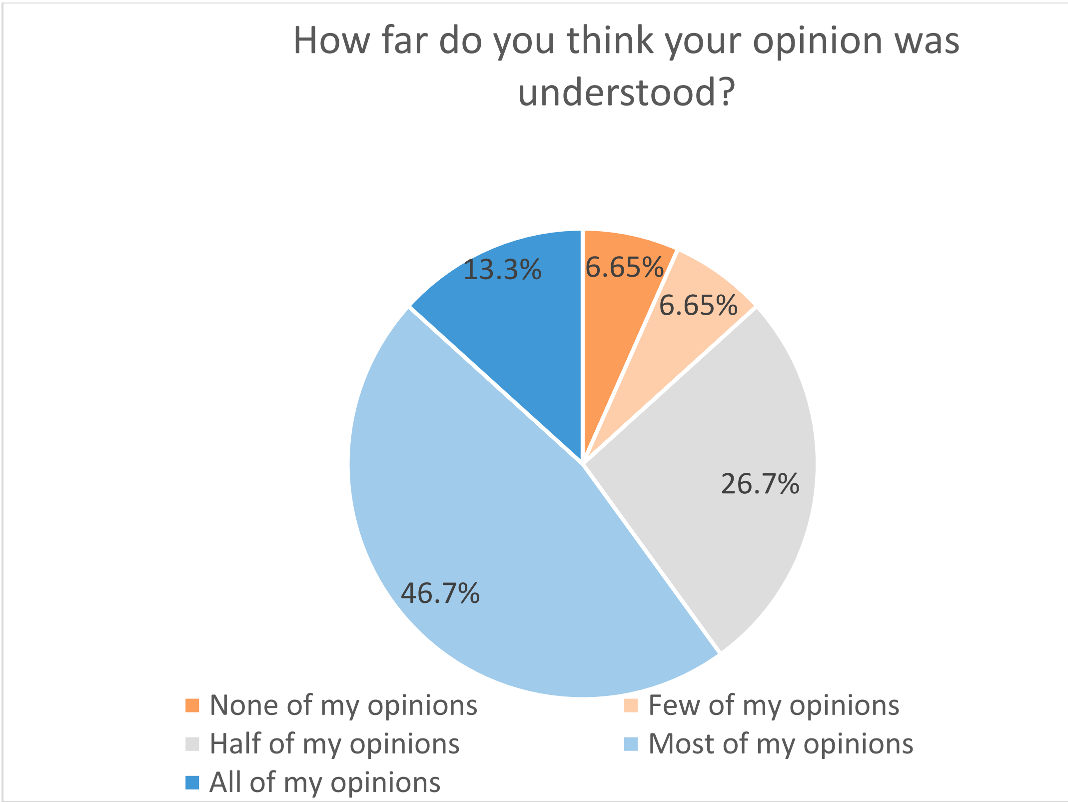


Fig 20. Group A Perception of Opinion Understood by Others

The above pie chart represents the survey result for the question "*How far do you think your opinion has been understood?*". For member belonging to Group A response in the survey is as following:

- 46.7% of the members responded that *most of my opinions* were understood while using the proposed process.
- 26.7% of the members responded that *half of my opinions* were understood while using the proposed process.
- 13.3% of the members responded that *All of my opinions* were understood while using the proposed process.
- Rest of the members responded that *none of my opinions and few of my opinions* were understood while using the proposed process.

*Group B:*

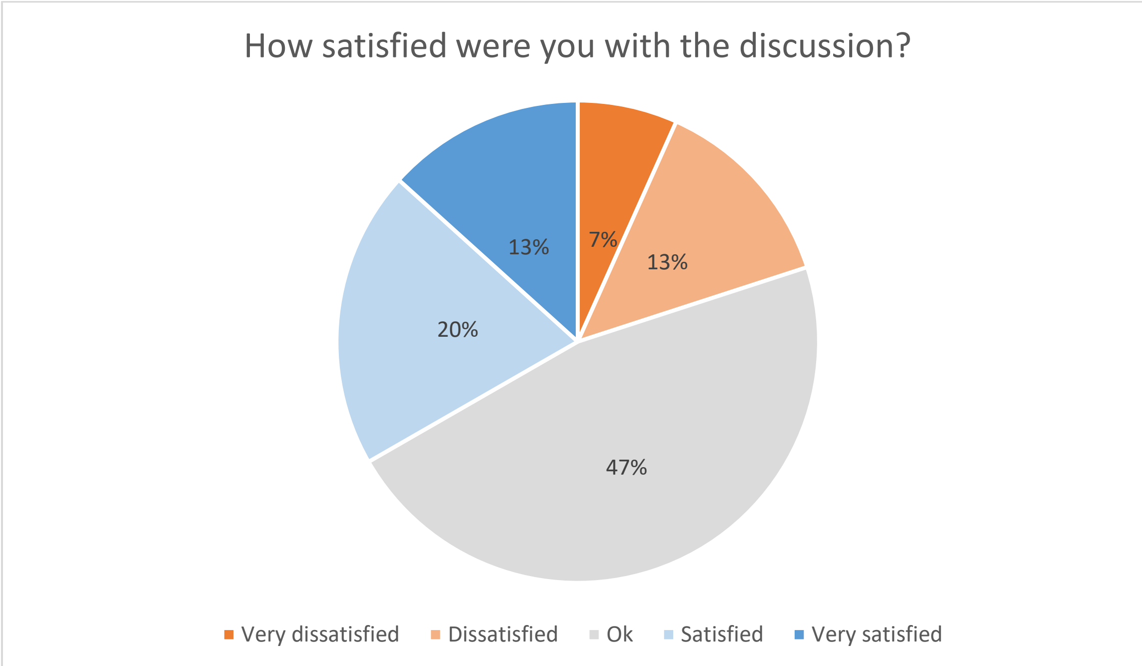


Fig 21. Group B Satisfaction Level

The above pie chart represents the survey result for the question "*How satisfied are you with the discussion?*". For member belonging to Group A response in the survey was as following:

- 47% of the members were *ok* with the discussion while using the proposed process.
- 20% of the members were *satisfied* with the discussion while using the proposed process.
- 13% of the members were *very satisfied* with the discussion while using the process.
- 13% of members were *dissatisfied* with the discussion while using the process.
- 7% of the members were *very dissatisfied* with the discussion.

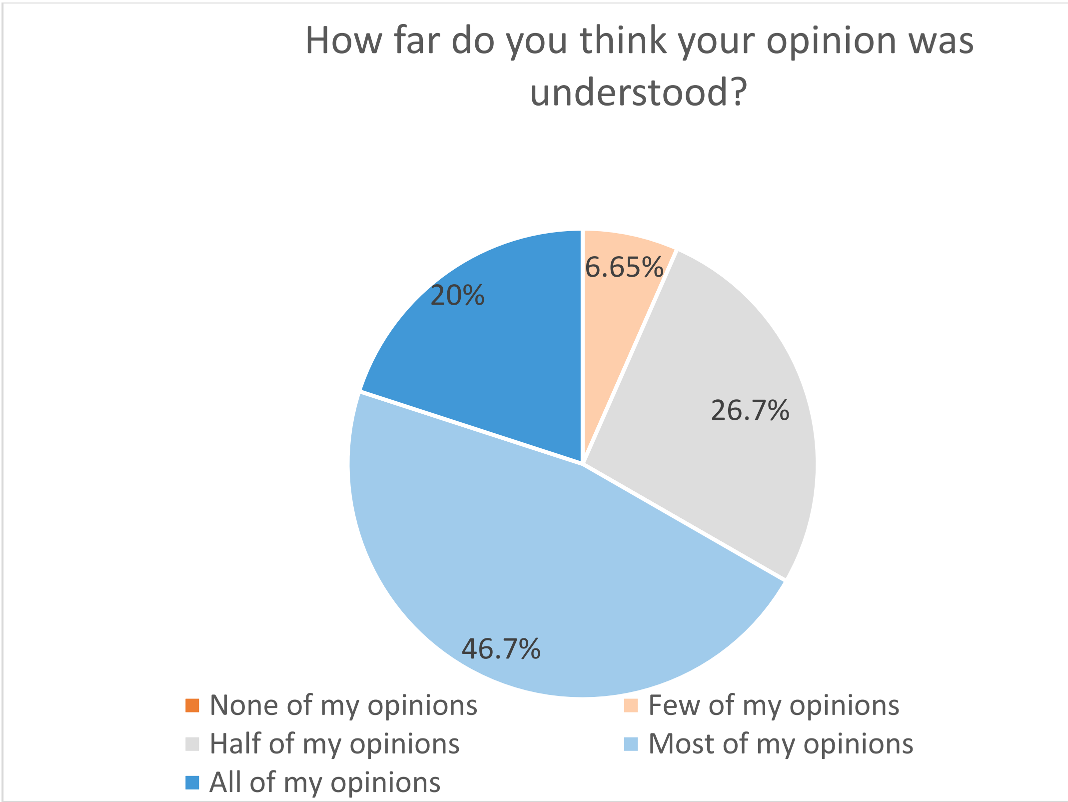


Fig 22. Group B Perception of Opinion Understood by Others

The above pie chart represents the survey result for the question "*How far do you think your opinion has been understood?*". For member belonging to Group A response in the survey is as following:

- 46.7% of the members responded that *most of my opinions* were understood while using the proposed process.
- 26.7% of the members responded that *half of my opinions* were understood while using the proposed process.
- 20% of the members responded that *All of my opinions* were understood while using the proposed process.
- 6.6% of the members responded that *few of my opinions* were understood while using the proposed process.

Table 18. Criteria 1 Fulfillment (Group A and B)

| Group A | Group B |
|---|---|
| • | • |

For the level of satisfaction about the discussion for Group A, 60% of the members were ok with the discussion, 13.3% were satisfied with the discussion, totaling to 73.7% of positive responses. For Group B, 46.7% of members were ok with the discussion ,20% were satisfied with the discussion and 13.3% were very satisfied with the discussion, totaling to 80%of positive responses. Thus, resulting in both Group, A and B fulfilling the Criteria 3.

Table 21. Criteria 2 Fulfillment (Group A and B)

| Group A | Group B |
|---|---|
| • | • |

For how much member thought that their opinion was understood by other member Group A, 46.7% of the member said most of their opinion were understood, 26.7 said half of their opinion were understood and 13.3% said all of their opinion were understood, totaling to 86.7 % of positive responses. For Group B, 46.7% of the member said most of their opinion were understood, 26.7 said half of their opinion were understood and 20% said all of their opinion were understood, totaling to 93.4% of positive responses. Thus, resulting in both Group, A and B fulfilling the Criteria 4.

### 4.4.3. Summary

After conducting the validation process for fulfillment of each criterion by comparing teams from Group A and Group B, it was evident that the proposed process used by teams in Group A had achieved higher levels of cognitive consensus while sharing knowledge with each other which was essential to the task process. In terms of member satisfaction during discussion both teams from Group A and Group B have positive responses above 50%. The same thing can be said about the team member's perceptions of other members understanding their opinion where both teams in Group A and Group B have received positive responses above 50%.Thus based on the validation results it leads us to believe that the virtual team member using the team process we have better chances of developing shared understanding and team mental model while sharing knowledge which are essential to task process and perhaps achieve better task results and team performance.

## 4.4. Discussion

The aim of the present work was to investigate the role of cognitive consensus process in virtual team collaboration during knowledge sharing activities, study the factors that influences and facilitate development of cognitive consensus in virtual teams and lastly to propose a process that improves task-related cognitive consensus in virtual teams.

### 4.4.1. Important Findings

Direct observations revealed that team members working virtually have a hard time which in common understanding about the task related information in general. Team members using the traditional method of knowledge sharing had the ability to share more ideas and opinions related to the task information compared to those using the proposed process of knowledge sharing. It may have happened due to the fact that the team member using the traditional way of knowledge sharing did not have to engage in the process of clarification of their ideas and opinions to other team members.

Another finding is that team members using traditional methods of knowledge sharing reported that they perceived that most of their ideas and opinions were understood by the other members, however the data used to verify the level of consensus have shown few percentages of consensus or common understanding about their ideas and opinion shared during collaborations. Compared to teams in Group A who have perceived that their opinions and ideas were understood by other members and the data used to verify had supported their claim by showing high levels of cognitive consensus and common understanding.

Even though the proposed process has performed better than the traditional process, team members from Group A have reported difficulties in performing the process steps due to its complexity and time-consuming nature. Compared to team members in Group B who reported that the traditional process is much easier, simpler to use and less time consuming.

Overall, the proposed process was able to improve the level of cognitive consensus and helped reduce the false sense of common understanding during virtual team collaboration.

### 4.4.2 Research Contribution

During this time of pandemic where companies took measure to reduce the spread of Covid-19 by advising the employees to work from home, causing the increase in the number of virtual teams and virtual collaboration worldwide, our research developed greater insights on the factors that facilitates common understanding among virtual team members, externalization of tacit knowledge which are important for the task process and team goal.

Another contribution involves the use of fuzzy mapping rating to help team members negotiate concepts which are deemed to be important to the task process based on their interpretation, preferences and expectations. In addition, our research wanted to contribute by proposing a systematic process, with clear steps that can help virtual teams clarify misunderstandings and reduce cognitive conflicts in the virtual environment.

Lastly, to help find the medium consensus level by using the interquartile range formula with the data generated from each team was another contribution.

#### 4.4.3 Limitations

One limitation from this study lies in the fact that the teams formed for the experiment were only composed of students in a controlled setting. Next research using the proposed process should try to apply it in real virtual teams to check the validity of the process in facilitating the development of cognitive consensus during knowledge sharing activities. Another limitation is that the nature of the task did not resemble the real task performed by virtual teams, future research should ensure that the task given to the team while performing the process is of the same nature as the ones used by virtual teams. The task also focused only on the design of the system and was very ambiguous. Other types of tasks should be experimented while using the proposed process.

# 5. CONCLUSION

The overall finding of the study is that the virtual teams while collaborating have the need to develop consensus during the knowledge sharing process in order to develop a team mental model which has a positive impact on team performance. In order to minimize misunderstanding and cognitive conflicts of task related knowledge virtual teams require a systematic approach that can help improve cognitive consensus. By doing so the virtual teams will have higher chances of achieving their task goal, coordinating their work accordingly and improving the decision-making process.

The proposed process was basically designed based on the three modes, virtual team, knowledge sharing and team mental model to see if the team members can achieve cognitive consensus while knowledge sharing. Group A, consists of 4 teams with three members each and with the data collected from this group it was verified and validated that out of 4 teams 3 teams were on high consensus level, which in a way directs that the proposed process could achieve a high level of cognitive consensus. On the other hand, Group B used the traditional method of knowledge sharing and from the data collected from this group of 4 teams, it was verified and validated that only 1 team out of 4 achieved a high level of cognitive consensus. During the survey it was noticed that both Group A and B scored a positive response above 50% when asked how satisfied they were about the discussion and where their opinions were understood by the other members.

Last but not the least, the proposed process qualified all the criteria used for the validation of the proposed process compared to the traditional method of knowledge sharing. Though the member of teams has suggested that the process consumes lots of time and about its complexity, Group A have performed very well giving us insight that the process can be further improved.

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