# PARTICIPANT-DRIVEN GROUP SUPPORT SYSTEMS: AN APPROACH TO DISTRIBUTED, ASYNCHRONOUS COLLABORATIVE SYSTEMS

by

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# DEDICATION

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# TABLE OF CONTENTS

TABLE OF CONTENTS - *CONTINUED*

# TABLE OF CONTENTS - *CONTINUED*

# LIST OF FIGURES

# LIST OF TABLES

# LIST OF TABLES - *CONTINUED*

# ABSTRACT

This dissertation presents the Participant-driven Group Support System (PD-GSS) framework. This framework presents an approach for Group Support System (GSS) designers to accommodate distributed or asynchronous groups through the use of different technologies and processes than traditional GSS.

The goal of the PD-GSS framework is to further involve the collaborative participants during the workflow in an effort to reduce the load on the meeting facilitator. As the name implies, it is the participants that are increasingly responsible for conducting and executing the required actions during a collaborative processes. The system empowers the participants in the meeting to conduct the meeting themselves, reducing the need for a dedicated facilitator to guide the process.

One of the modules from the PD-GSS framework, Peer-reviewed Brainstorming, was developed into a prototype and tested experimentally. This module requires each brainstorming idea to be routed through a peer-review process whereby the original brainstorming idea is edited for clarity and completeness. The goal of this new module is to reduce the number of low quality, noisy comments while increasing the quantity of high quality comments.

Ten six-person groups participated in the first experiment. Five groups were placed in a traditional electronic brainstorming GSS while the other five groups were placed in the peer-review treatment. The results indicate that the peer-review process

did control the brainstorming process, yielding a higher percentage of valid brainstorming ideas.

The second module examined was the categorization module, allowing groups to work autonomously to identify similar ideas that should be grouped together in the same category or bucket. This new approach to the categorization of brainstorming ideas enables groups to work independently, asynchronously, and anonymously to organize the brainstorming input.

An existing GSS, ThinkTank by GroupSystems, was utilized. Eighty-one groups were used in the second experiment to test the ability of groups to work independently, without a facilitator, in an attempt to organize brainstorming ideas. The groups working synchronously outperformed the groups working in a mock asynchronous setting. Likewise, the groups that had to categorize the fewest number of brainstorming ideas received the highest performance measures.

# CHAPTER 1 – INTRODUCTION

> "What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention, and a need to allocate that attention efficiently among the overabundance of information sources that might consume it."
>
> -Herbert Simon

This chapter overviews the purpose of this research, demonstrating the need for improved asynchronous collaboration and the potential benefits. The research approach selected for this research is discussed and the organization of the dissertation is presented.

## 1.1. Purpose and benefits of collaboration research

This research provides the first evaluation of a participant-directed collaborative framework called Participant-driven Group Support Systems (PD-GSS). This framework seeks to empower the participants by enabling the completion of collaborative activities without the required intervention of a skilled facilitator. The framework coalesces the ideas and inputs of the group into a consensus that can be used for decision-making purposes. The framework also enables the ability of the group to participant in asynchronous and distributed collaborative activities. The two experiments in this research serve to further understand the framework and the abilities of a group to collaborate effectively without a facilitator. This research seeks to form a foundation for further research on asynchronous, distributed collaboration and PD-GSS.

Work within organizations frequently occurs within the context of project teams. This is especially true within the information economy as organizations seek to harness the skills and abilities of a variety of people to address a given problem, opportunity, or decision-making opportunity (Galegher & Kraut, 1990). Group work provides many advantages as the individuals within the group are able to share information, generate ideas, make decisions, and review the effects of the decisions (Phillips & Phillips, 1993). The goal is to have the group come to a "better" decision than would have been possible because of the collective knowledge, skill, and expertise of the group is greater than that of any individual (Maier & Hoffman, 1960; Martz, Vogel, & Nunamaker, 1992).

The premise that pooling intellectual assets of the group creates value is illustrated in an example in the book The Wisdom of the Crowds: Why the Many Are Smarter Than the Few and How Collective Wisdom Shapes Business, Economies, Societies and Nations (Surowiecki, 2004). In the example, British scientist Sir Francis Galton visited a country fair in 1906. At the fair, a raffle was held to judge the weight of an ox after it had been slaughtered and dressed. Each individual that entered the raffle wrote down his guess and submitted it. Galton acquired all of the guesses for the raffle after the event was completed. A grand total of 800 people entered the raffle and guessed the weight of the ox. Galton averaged the guesses and noticed that the guesses formed a normal distribution and yielded an average weight of 1,197 pounds. The actual weight of the ox was 1,198 pounds. The group average was only off by one pound. What is interesting to note is the composition of those who participated in the raffle. Galton was not expecting a large group of individuals to accurately guess the weight of the ox as a majority of the participants in the group most likely had little or no expertise in judging the weight of an ox.

> "Galton undoubtedly thought that the average guess of the group would be way off the mark. After all, mix a few very smart people with some mediocre people and a lot of dumb people, and it seems likely you'd end up with a dumb answer. But Galton was wrong." (Surowiecki, 2004)

This anecdote illustrates the principle that groups may perform well by leveraging the skills and abilities of the different people within the group.

## 1.2. Decision-making background

Herbert Simon stated that attention is the scarce resource in human decision making. This leads to Simon's notion of "satisficing" (Simon, 1965), or that humans will choose the first option that satisfies the requirements instead of searching for the optimal solution. Simon stated that searching for an optimal solution is an exhausting and potentially futile process (Lipshitz, Klein, Orasanu, & Salas, 2001). This notion of allocating scarce resources highlights the importance of the group processes and tools used in collaborative work. The support tools must provide a mechanism to efficiently and effectively leverage the attention resources of the individuals within the group. Likewise, the process must also be designed to maximize the return on investment of the human attention resources.

Lipshitz et al (2001) define team decision making as containing the following components: gaining situation awareness, building shared mental models, and sharing problem assessments. The authors note that all of these steps could be used as part of a decision-making process for a cognition problem. The current research seeks to further research in computer-based tools to enable groups to accomplish these activities in order to achieve a stated objective. These components of team decision making are encompassed in the functionality of the decision making software to be discussed later.

Simon defined the decision-making process as having the following general steps: intelligence, design, and choice (Simon, 1965). This decision-making process is similar to Mintzberg's framework of identification, development, and selection (Mintzberg, Raisinghani, & Theoret, 1976). In the intelligence step, group members can exchange relevant information. The design stage is the development of potential options or decision alternatives. The choice involves the process of selecting the option determined to be the best. This basic process is encompassed in the computer-supported group workflow. Groups are able to exchange information to first understand the problem and contextual requirements, develop alternatives or potential solutions, and select the best course of action. This overall decision-making process is utilized in the current research project.

Achieving quality results within the group context requires certain conditions to be met: diversity, independence, decentralization, and aggregation (Surowiecki, 2004).

**Diversity of opinion**: Each person should have some private information, even if it's just an eccentric interpretation of the known facts.

**Independence**: People's opinions are not determined by the opinions of those around them. The lack of independence leads to phenomena such as groupthink that reduce the efficacy of the group.

**Decentralization**: People are able to specialize and draw on local knowledge. Decentralization promotes a diversity of opinion that accompanies independence.

**Aggregation**: Some mechanism exists for turning private judgments into a collective decision. In other words, there must be some mechanism in the group work where each individual can voice his or her opinion and the majority opinion is tabulated.

These characteristics enable the effective harnessing of group intellect. As illustrated in the Galton example in The Wisdom of Crowds, the power lies not in leveraging solely the experts but a variety of talents and intellects. James March (1991) expressed this sentiment in the following quotes:

"The development of knowledge may depend on maintaining an influx of the naive and the ignorant, and ... competitive victory does not reliably go to the properly educated" (p. 86).

"[The] effect does not come from the superior knowledge of the average new recruit. Recruits are, on average, less knowledgeable than the individuals they replace. The gains come from their diversity." (p. 79)

This sentiment is echoed in The Wisdom of Crowds. The author states that homogenous groups are great at what they do well but that they become progressively less able to identify and research alternatives (Surowiecki, 2004). Homogenous groups spend too much time exploiting and not enough time exploring the alternatives (March, 1991). Similar thoughts are echoed by Russo and Schoemaker, stating that moderate amounts of task related conflict are necessary to improve group performance (Russo & Schoemaker, 2002). This task conflict stimulates increased critical analysis, more thorough examination of the problem, and potentially more thorough and exhaustive searching of the solution space.

These components of productive teams specify certain requirements and functionalities that a computer-based support system must enable or foster if the group is to be more productive than an individual. The design of the current research seeks to enforce these characteristics, improving the probability of the group being productive and meeting its objectives. The goal is to leverage a wide range of individual expertise, intellect, and perspective to improve group decision making.

## 1.3. Group Support Systems (GSS)

Group decision making and problem solving has seen dramatic changes with advances in modern technology. This technology allows individuals to communicate and collaborate in ways that were previously not feasible. One of these technologies is Group Support Systems (GSS), which enable groups to perform collaborative tasks such as decision making or problem solving in a technology-supported manner.

GSS is a combination of hardware, software, people, and processes that enables collaboration between groups of individuals (Sprague & Carlson, 1982). GSS can increase the productivity of a group by effectively harnessing and leveraging the human capital in the group (Adkins, Burgoon, & Nunamaker, 2003; J. F. Nunamaker, Jr., Dennis, Valacich, Vogel, & George, 1991). According to Nunamaker et al (1995), GSS increases productivity through such things as increased information flow between the group members, more objective evaluation of information, and synergy within the group.

There are both tangible and intangible benefits associated with using GSS (de Vreede, Vogel, Kolfschoten, & Wien, 2003). The tangible benefits include such things as reducing the amount of time and resources required to complete the meeting requirements as compared with traditional, non-technology supported meetings (Grohowski, McGoff, Vogel, Martz, & Nunamaker, 1990; J. F. Nunamaker, Jr., Briggs, Mittleman, Vogel, & Balthazard, 1996; Post, 1992). Other tangible benefits include such things as generating an increased number of higher quality brainstorming ideas (Dennis, Valacich, & Nunamaker, 1990; Gallupe, Bastianutti, & Cooper, 1991; Gallupe et al., 1992).

The intangible benefits associated with GSS usage are, obviously, more difficult to quantify. However, these benefits include such things as improvements in the level of group cohesiveness, improved problem definition, and stronger commitment from the group to the solution (J. F. Nunamaker, Jr. et al., 1996).

Research has shown that these positive effects from GSS usage increase with the size of the group (Fjermestad & Hiltz, 1998; Gallupe et al., 1992; J. F. Nunamaker, Jr. , Dennis, Valacich, & Vogel, 1991). Fjermestad and Hiltz (1998) reviewed 200 GSS studies that were published in 230 articles. Their results indicated that the benefits of GSS usage became more pronounced as the size of the group increased. The studies reviewed showed that larger groups outperformed smaller groups in a variety of GSS environments. It is important to note that most of the experiments reviewed had group sizes that were small to medium in size; the largest groups reported included 24 members. The need still exists to fully investigate large groups and at what size the correlation between group size and improved benefits is reduced or terminates.

Experimentation with large, asynchronous, distributed groups presents numerous difficulties for researchers, practitioners, and the GSS tools. As a result, not much research has been conducted in this area. There is a need to further enhance the ability of GSS tools and frameworks to accommodate asynchronous, distributed groups. The same affordances that enable asynchronous collaboration will also allow for larger groups to collaborate in a more effective manner.

## 1.4. Group productivity

One theory that addresses the ability of a group to be productive and achieve its stated objective is Team Theory (Briggs, 1994; Briggs, Reinig, Shepherd, Yen, & Nunamaker, 1997), see Figure 1. Previously known as Focus Theory, Team Theory provides a causal model for the productivity of a group in making a joint, cognitive effort toward some stated objective. Productivity is defined as the degree to which the group meets the objectives. This theory posits that one of the key limits on group productivity is the limit on human attention resources. As illustrated in the figure, the collaborative process requires time; cognitive effort must be exerted over a potentially significant amount of time.

According to Team Theory, the limited human attention resources must be allocated among several competing tasks: communication, information access, and deliberation. The amount of cognitive effort available to allocate to these three activities over time is a function of both the level of congruence between the goals of the group and the goals of individual participants as well as the level of distraction to the group.

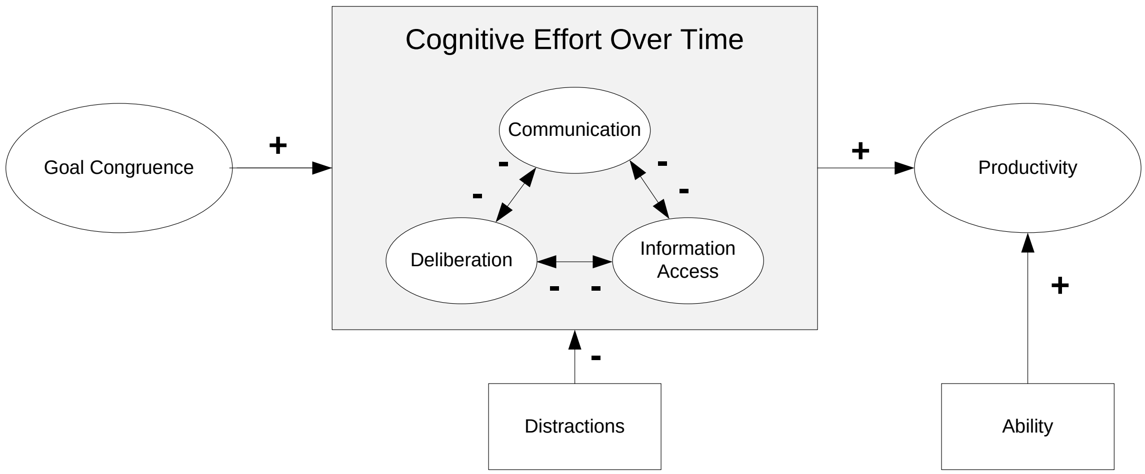


Figure 1: Team Theory of group productivity

Communication is defined as the process of the sender creating stimuli to convey meaning to the receivers. The receivers then receive the stimuli and assign meaning to them. In a traditional GSS scenario, communication is executed primarily in a text-based medium, limiting the diversity and richness of the stimuli (Daft & Lengel, 1986; A. R. Dennis & J. S. Valacich, 1999).

Deliberation is defined as the cognitive tasks “required to form and execute intentions with respect to the group goal” (Briggs et al., 1997, p. 95). The definition of intention includes both the desired goal plus the actions required to achieve the goal.

Information access is defined as the trade-off between the benefits associated with obtaining additional information versus the cognitive costs associated with receiving and processing the information. Team Theory posits that one of the key functions of the dissemination of information within the group is to increase the probability that the predicted outcome will be obtained by choosing one course of action over the others. However, information that is shared by the group only has value to the extent that it is timely, accurate, and complete (Briggs, 1994). The potential benefit of the new information that is shared is offset by the cost of acquiring, storing, processing and retrieving it. In summary, the information can be valuable but this value comes at a cognitive cost to the group participants. Limited cognitive resources are required to process any new information that is generated and shared by the members of a group.

The GSS process must mitigate these cognitive expenditures such that the increased information flow does not negatively affect the overall productivity of the group. As a group moves to an asynchronous and distributed environment, the ability and ease with which the group members can communicate and collaborate is reduced. Likewise, as the size of the group grows, the volume of information communicated may induce a large cognitive burden on the participants, potentially stifling the collaborative process.

## 1.5. Levels of collaborative work

Research by Nunamaker et al (1996) posits that there are three levels of group work:

**Individual** - this is a setting in which there is uncoordinated group work. Nunamaker et al compare this to a group of sprinters, each exhibiting effort but in an uncoordinated, individual manner.

**Coordination -** this level of group work is coordinated but independent. The analogy for this level of group work is a relay team at a track event. The members of the team each work together to an extent for the good of the team but each member is still working on an individual basis.

**Group dynamics level** - this is the highest level of group work; the group works in a concerted effort toward the end goal. This requires a higher level of coordination and communication than the previous levels of group work.

In an asynchronous, distributed setting, it is possible to engage a group to perform at the first two levels of group work. People can function in distributed teams and work in concert toward a common goal. However, achieving a true group dynamic in a distributed, asynchronous setting requires new tools and processes in order to be effective. This research seeks to improve the ability of groups to work together at a group dynamic level in asynchronous, distributed meetings through new tools and processes. This new approach also lays the foundation for collaboration between larger and larger groups.

## 1.6. Research question

The overarching research question guiding the development of the conceptual framework and the prototype within this research project is as follows:

Can an improved GSS system be built that could accommodate asynchronous, distributed groups?

More refined and specific research questions will be presented in the different GSS modules that are examined experimentally in later chapters.

This work is largely exploratory in nature. A large volume of literature addresses GSS design, development, and usage but little research exists on procedures and tools that are designed to handle asynchronous and distributed groups. This work seeks to establish one way of addressing the problems associated with collaborating with asynchronous, distributed groups in the hopes of furthering research in this area.

## 1.7. Research approach

Due to the exploratory nature of this research, formal hypotheses will not be examined as there is not sufficient prior art from which to base hypotheses. This research seeks to examine the feasibility of a new system to enable asynchronous, distributed collaboration that could be extended to large groups. To achieve this end of proof of feasibility, a multi-methodological research approach is utilized. This multi-methodological approach includes building a conceptual model, developing a system prototype, and conducting laboratory experimentation. This research approach is discussed in detail in Chapter 4.

## 1.8. Goals and contributions of research

This research seeks to present a new GSS framework that enables a more flexible form of collaboration processes and technology. The goal of this research and the new framework is to allow collaboration between individuals that are geographically and temporally distributed.

The contributions of this research include providing a framework and a set of tools that practitioners and researchers can use to further enhance GSS abilities and relevance. These results also seek to inform GSS designers on how to improve the flexibility of GSS applications in order to be used in more diverse contexts.

## 1.9. Overview of the dissertation

The remainder of this dissertation is organized as follows. Chapter 2 presents a review of GSS literature, GSS workflows, and the features and limitations of research in this area. Chapter 3 presents the new conceptual framework for asynchronous, distributed collaboration. This chapter includes discussion of the prototype development and associated design decisions. Chapter 4 presents the multi-methodological research approach utilized in this research project. This chapter also introduces the two experiments conducted. Chapter 5 presents the statistical analysis and results from these experiments. Chapter 6 discusses these results and their implications in light of the current GSS literature and PD-GSS framework, including the limitations of the experiments. Chapter 7 presents a summary of the findings, the conclusion, and future directions for additional research in GSS.

# CHAPTER 2 – LITERATURE REVIEW

This chapter presents an overview of GSS usage and research, including discussion of a typical GSS workflow. It also discusses the process gains and losses associated with GSS usage.

## 2.1. GSS workflow and collaborative activities

Collaborative activities conducted via GSS tools and methodologies follow a general workflow pattern. Figure 2 illustrates a typical GSS workflow. This figure is taken from Groupsystems.com, one of the first GSS applications developed in academia and available to industry.


Figure 2: Collaborative workflow from Groupsystems.com

The activities within this figure map to different phases within a general goal attainment process (Kolfschoten, Briggs, Appelman, & de Vreede, 2005):

1. Understand the problem
2. Develop alternative solutions
3. Evaluate alternatives
4. Choose an alternative
5. Make a plan
6. Take action
7. Monitor the outcome

The group begins with the problem at hand or the task that the group is engaged to address. In the figure, this is denoted by the challenge and is the start or the impetus for the collaborative effort. At this stage, the meeting coordinator or owner identifies the challenge that the group needs to work toward. This challenge may take the form of a problem solving exercise (e.g., how do we combat the shrinking enrollment problem facing our department?) to planning strategic operations (e.g., what product line should we focus on?). The challenges may be different structurally in that some are closed-ended problems, where there is potentially one ideal solution, while others are open-ended problems. During this stage, the group attempts to understand the problem and the objective of the collaborative meeting.

The next step in the collaborative process is what is identified in the figure as Generate. This activity is generally a type of brainstorming activity that allows the group to develop ideas, alternatives, or potential solutions to the challenge at hand. During brainstorming activities, the group seeks to generate as many ideas as possible, without considering the feasibility or plausibility of the ideas at that time (Couger, 1995; Osborn, 1953). The goal is to generate innovative thought that sparks the group to develop creative and previously unthought of ideas. These types of activities can be classified as divergent activities. Divergence refers to the notion that the group tries to generate new ideas or information on a given topic, moving from a state of having fewer ideas to a state of having more ideas (Briggs, Vreede, & Nunamaker, 2003). The outcome from the divergence activities is a set of unsorted, uncategorized, and unorganized ideas that need to be synthesized by the group. This leads us to what can be classified as convergent activities.

Convergence is the process of the group moving from having many ideas to fewer ideas through refinement and organization processes. In these processes, the group synthesizes the divergence data so that the information is accessible and not overwhelming. In our figure, the next step is to Categorize. During the categorization process, the group proceeds to examine each brainstorming input to determine appropriate categories to which the brainstorming input belongs. In this process, the brainstorming ideas are coalesced into topic areas or threads that enable the group to identify key areas that need attention or potential solution areas to the challenge.

The categorization process yields two additional results in addition to the organization of the ideas. First, the ideas are distilled down so that redundant ideas are removed. The group combines and consolidates similar brainstorming ideas so that the end result is a more refined list of brainstorming ideas that is easier for the group to process cognitively. Second, during the categorization process, brainstorming ideas are clarified. Oftentimes, the brainstorming idea itself may not be entirely clear or may contain terminology that is unfamiliar or inconsistently used by the members of the group. During the categorization process, the group is able to refine the brainstorming ideas and clarify any ambiguous terminology. The end result of these convergence activities is a set of consolidated brainstorming ideas that are organized, distilled, clarified, improving the ability of the group to work with the information and hopefully yield a better solution or outcome.

After the categorization process, the group can move toward other activities that narrow down the potential solutions or alternatives. These activities include various voting tools that enable the group to rank the ideas or alternatives or simply identify the top ideas that deserve further attention (Weisband, 1995). These rankings and voting activities can be performed iteratively until the group may reach a certain level of consensus and develop an action plan or appropriate follow-up activities.

The collaborative activities themselves can be thought of as belonging to one of the five patterns of collaboration (Briggs et al., 2003). Collaborative engineering researchers have identified various categories of activities to which these different collaborative activities belong. The patterns of collaboration include the following:

- Diverge: Moving from a state of having fewer concepts to a state of having more concepts
- Converge: Moving from a state of having many, unrefined ideas to a state of having a reduced set of ideas that are worthy of further attention.
- Organize: Improving the understanding of the relationships between ideas.
- Evaluate: Improving understanding of the possible consequences of each idea.
- Build consensus: Improving the level of agreement.

These five patterns of collaboration overlap with the overall goal attainment process. Figure 3 represents how each pattern of collaboration fits within this larger goal attainment framework.

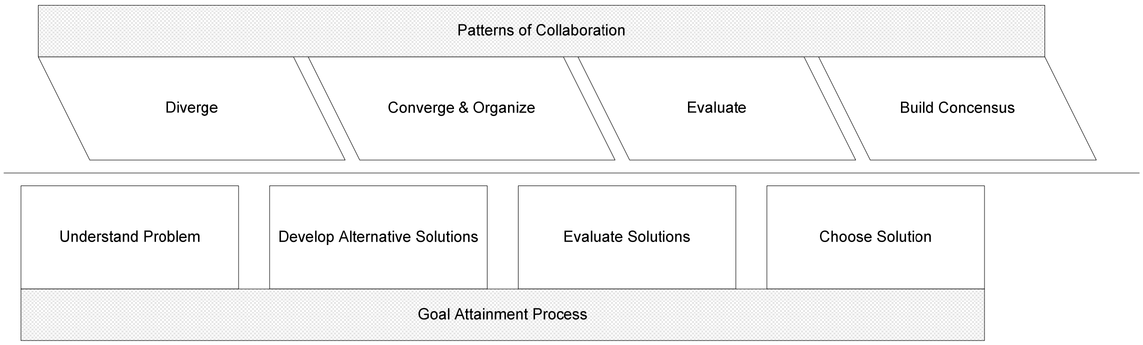


Figure 3: Patterns of collaboration and goal attainment process

Research by Chen et al (1994) reviewed the relative duration of these types of activities as well as the participant satisfaction levels associated with them, see Figure 4.

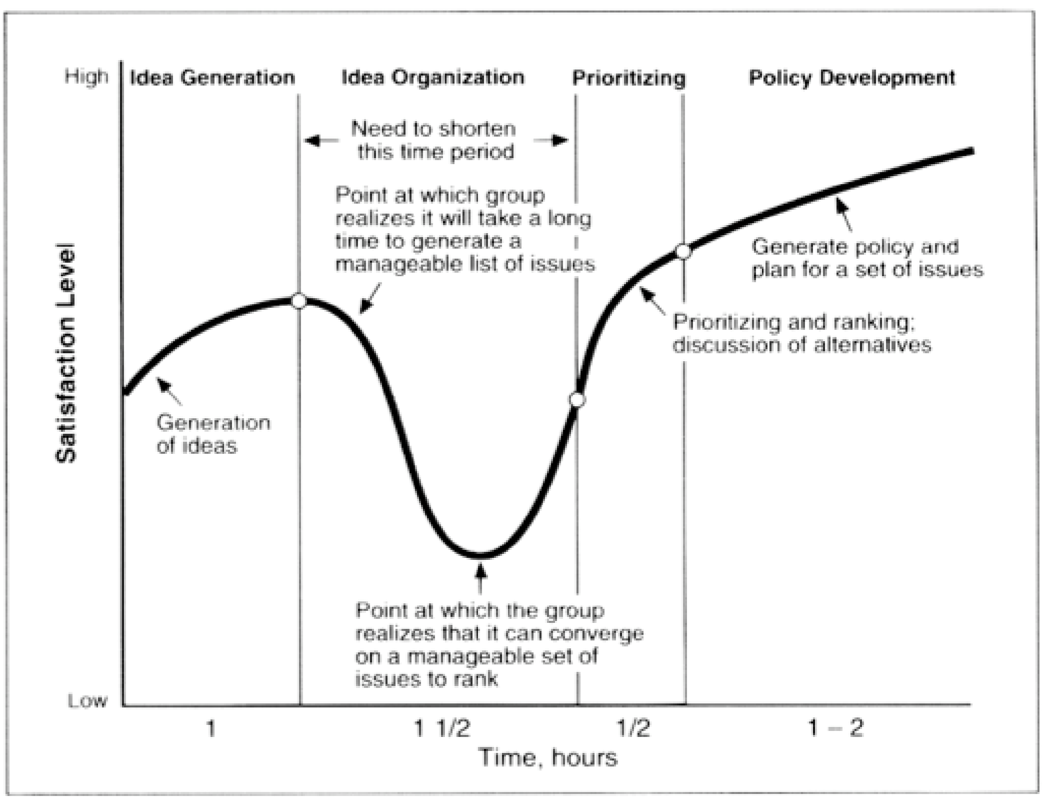


Figure 4: Satisfaction levels over time for the collaboration stages (Chen et al., 1994)

The first step in the figure is the "idea generation" activity. We can see that this activity generally lasts around an hour. However, the actual time given is not as important as the relative duration compared with the other activities in the figure. During this activity, satisfaction levels in the group are high as the group may generate a number of good ideas; the participants feel that the activity is worthwhile and valuable as numerous ideas are developed and shared. However, the next collaborative activity, Idea Organization, or what we called categorization, is a longer, less satisfying process. The group realizes that it is a difficult, cognitive intensive task to organize and make sense of all the brainstorming ideas. This activity requires an increase in cognitive expenditure as the ideas may be numerous, complex, and disparate. According to the authors, this activity takes one and a half times as long as the idea generation or brainstorming activity. This also leads to decreased satisfaction levels. Once the ideas have been organized, the prioritization, or what we call evaluation, requires less time than the previous activities and once again improves the satisfaction levels of the group. The group is again able to see the benefit of the meeting as tangible, concrete ideas or solutions bubble to the top and are selected by the group. The last activity, Policy Development, is similar to what we have defined as the action plan development. Depending on the context and the challenge at hand, this activity varies in duration. This activity is associated with favorable satisfaction levels, most likely since the group feels the efforts are valuable in producing an outcome that is of worth to the group.

What is important to note in this graphic is that the convergence activities (idea organization) represent a challenge to the collaborative effort, for both the facilitator as well as the participants themselves. As stated in Briggs et al (2003), there has been considerable research devoted to the divergence activities. However, Briggs et al continue to state that not enough research has been conducted in the area of convergence and that this area needs focus. Convergence activities represent a more challenging component of the collaborative activities due to the increased level of cognitive effort and the need to utilize or develop some level of consensus within the group. Part of this research seeks to address these shortcomings by investigating the convergence process in an effort to improve the efficacy of this collaborative activity.

## 2.2. Facilitation

One of the characteristics of traditional collaboration is the utilization of a facilitator. The facilitator is generally an independent party that is designated as the person to guide the group through the collaborative group work and provide expertise with the collaborative tools. Facilitator expertise ranges from professional facilitators to those that can run the collaborative tools and help the group perform basic tasks within the GSS software. Research has shown that the facilitator plays a large role in the productivity and outcome of the group (Anson, Bostrom, & Wynne, 1995; Briggs, De Vreede, Nunamaker, & Tobey, 2001; George, Dennis, & Nunamaker, 1992; Griffith, Fuller, & Northcraft, 1998; J. F. Nunamaker, Jr. et al., 1991; J. S. Valacich, Dennis, & Connolly, 1994). Depending on the expertise of the facilitator, the experience, and the level of involvement, the facilitator can heavily influence the outcome of the group (Aakhus, Adkins, & Glynn, 1997).

The responsibilities of the facilitator can be classified according to three major areas of process support the facilitator provides (J. F. Nunamaker, Jr. et al., 1991). These different levels of process support alter the level to which the facilitator is involved in the group work.

The first type of process support is referred to as the chauffeured style. In this type of GSS meeting, only one person uses the GSS tool (J. F. Nunamaker, Jr. et al., 1991). This individual is generally the meeting facilitator or meeting leader. In this fashion, one computer is hooked up to a display where the balance of the group can watch what is occurring on the GSS system. The structural affordances of this type of meeting indicate that the group must verbally discuss items and that the facilitator is the only one required to utilize the technology to enter the information into the GSS tool. Limited technological resources are required in this style and no GSS knowledge is required for the GSS participants.

The second type of process support is referred to as the supported style (J. F. Nunamaker, Jr. et al., 1991). In this type of meeting, each participant is located at a computer and is responsible for interacting with the GSS tool. Each member of the group is now able to communicate in parallel and in anonymity. Group communication takes place via both the text-based GSS tools as well as verbal discussion. In this type of support, the facilitator is responsible for teaching the group members how to use the technology and providing technical support during the process. Likewise, the facilitator is responsible for guiding the verbal discussion that takes place in the room, ensuring that the group stays on task.

The last level of process support is the interactive style. This type of meeting is similar to the supported style in that everyone in the meeting is situated at a computer terminal and interacts with the GSS tools individually. However, the interactive meeting utilizes the GSS tools to accomplish a vast majority of the communication (J. F. Nunamaker, Jr. et al., 1991). This type of communication helps to ensure the anonymity and autonomy of the group members. Again, in this type of meeting the facilitator has responsibility for ensuring that each participant can use the GSS tools to collaborate with the group.

Research efforts have focused on ameliorating the responsibilities of the facilitator by implementing intelligent software or agents to aid the facilitator (Aiken, Sheng, & Vogel, 1991; Wong & Aiken, 2003). This research shows promise in aiding the facilitator in executing the administrative responsibilities associated with guiding the meeting. These types of aids are most appropriate to the interactive style of facilitation.

Research by Nunamaker et al (1991) has shown that each of these different types of support have its own strengths and weaknesses. No one type is absolutely preferred over the others, as the choice depends on the context of the meeting. It should be noted that the outcome of the group is also influenced by the selection of process support level (Dickson, Partridge, & Robinson, 1993; Limayem, Lee-Partridge, Dickson, & DeSanctis, 1993; J. F. Nunamaker, Jr. et al., 1991; Romano, Briggs, Nunamaker, & Mittleman, 1999). This research presents a new framework for GSS interaction that can be classified under the interactive style. This research seeks to have all interaction and communication take place via a text-based GSS tool, enforcing anonymity and autonomy.

## 2.3. Facilitator bottleneck

Research has shown that groups utilizing GSS technologies are often more productive than groups that are not assisted by technology (Fjermestad & Hiltz, 1998). However, despite the productivity enhancements, GSS usage has not been widely adopted. Research by Briggs et al (2003) attempted to understand why existing, successful GSS installations fall into disuse. The authors concluded that there are several factors that could make a GSS installation "self-extinguishing". These factors include economic and political causes.

According to Briggs et al, there are a handful of economic factors that hinder the ability of an organization to maintain a thriving GSS installation. One of the factors identified is the cost of the facilitator. The authors state that typical work departments or units often have routine, repeatable tasks and that it is rare for a special problem to surface that would justify the expense of the facilitator. These types of problems are special events that are not typically encountered within one specific work group or department. The inertia or lack of routine to utilize the GSS presents a formidable barrier. The authors further state that the expense of a full-time facilitator is often one of the first items to be cut during budget crunches. When the facilitator is removed from the organization, the desire and ability to hold GSS sessions is reduced.

The second group of factors limiting GSS installations is the political component. Briggs et al state that GSS facilitators must possess various skills to be effective. These skills and attributes include the following (Briggs et al., 2003, p. 41):

- a good communicator
- a task-focused problem solver
- a people-person who perceives group objectives and understands group dynamics
- experienced with configuring and maintaining the GSS systems
- flexibility
- leadership

Given that these attributes are highly desirable among employees, facilitators are often promoted or reassigned to other areas, most likely leaving the GSS installation without another skilled facilitator to handle the facilitator responsibilities.

The end result of both the economic and political factors is that the GSS installation is left without a skilled facilitator to lead collaborative groups and champion the use of GSS. Without a proper facilitator, groups often have a difficult time structuring and executing collaborative work. For these reasons, Briggs et al propose a framework called Collaboration Engineering that aims to empower the participants of the meeting, thus reducing the dependence on a facilitator. The goal of Collaboration Engineering is to reduce the facilitator bottleneck by enabling the participants to facilitate their own meeting, thus increasing the probabilities that GSS installations will stay active and ingrained in organizations.

To empower the participants, Briggs et al (2001) propose the notion of a thinkLet, which as they describe it, is "the smallest unit of intellectual capital required to create one repeatable, predictable, pattern of collaboration among people working toward a goal" (p. 46). The thinkLet is a discrete unit of work that is part of a collaborative process. Each thinkLet is composed of the following three parts:

1. Tool - the software and hardware technology that the group uses to collaborate
2. Configuration - the details on how to specifically configure the tool depending on the needs of the group
3. Script - the instructions and processes given to the group so that they can execute the collaborative work

The notion behind thinkLets is that participants can leverage the modular collaborative components, putting together a group process that consists of various thinkLets. Each thinkLet provides both the tools and the instructions necessary to empower the participants of the meeting to perform in the capacity of a facilitator, while reducing the cognitive load normally associated with the facilitator role. Briggs et al propose certain thinkLets and others have been proposed as well that can be used as blocks to build a complete collaborative workflow (Briggs et al., 2001; Briggs et al., 2003; de Vreede & Briggs, 2005; Harder & Higley, 2004; Kolfschoten et al., 2005; Santanen & de Vreede, 2004).

This concept of empowering the participants while reducing the dependence on a facilitator is also a key concept of the Participant-driven GSS framework. This topic will be discussed further in chapter 3, where the PD-GSS framework is introduced.

## 2.4. Process gains and losses

One of the hallmarks of Group Support Systems has been the improvement in process gains and decreases in processes losses as compared to traditional group meetings in specific contexts and uses. The composition and structural affordances of GSS usage in a group collaborative process enables significant benefits over traditional face-to-face meetings. These benefits are known as process gains (Steiner, 1972). GSS usage also affects the negative aspects of group work, often reducing the process losses but sometimes amplifying the process loss.

One of the functionalities of GSS that improves the group process is that of parallel communication (Dennis, George, Jessup, Nunamaker, & Vogel, 1988). Each participant within the GSS meeting is located at a computer terminal. Each member of the group can participate autonomously with the group at the same time via the GSS session. The important thing to note is that each participant can communicate and interact simultaneously. In face-to-face meetings, each member of the group must wait until the current speaker finishes before the next person may commence speaking. This phenomenon is known as production blocking and is one of the process losses of group work (Diehl & Stroebe, 1991; J. F. Nunamaker, Jr. et al., 1991). GSS usage decreases the attention blocking process loss as all members of the group can express their ideas at the same time via text-based interaction on the GSS. For example, in a brainstorming session, each member of the group can enter new brainstorming ideas, or comment on other brainstorming ideas, concurrently. No waiting to speak or turn taking is involved.

This increased flow of information is one of the recognized process gains from the utilization of GSS for group work. Groups can freely exchange more information than traditional groups without GSS technology. This is related to other improvements in process gains, including such things as synergy, stimulation, and more objective evaluation (J. F. Nunamaker, Jr. et al., 1991). Cognitive synergy refers to group members sparking ideas in each other. This notion is also identified by the phrase that the group is greater than the sum of its parts. Synergy is tightly correlated with stimulation, where the GSS enables rapid feedback from a wide variety of individuals on a given idea or topic.

It is important to note, however, that this decrease in the attention blocking process loss is dependent on the contextual factors of the group process. These contextual factors include which collaborative activity the group is currently engaged in. The various collaborative activities each possess differing requirements, processes, and characteristics that alter how the group may interact. For example, when the group is brainstorming ideas, GSS allows parallel communication. Each member of the group can brainstorm ideas simultaneously, improving the efficiency of the brainstorming activities. However, this parallel communication quality does not hold for all collaborative activities within a group collaboration process. For example, one activity that must take place after brainstorming is the process of categorizing the brainstorming ideas. The categorization process essentially performs two functions. First, the ideas themselves are refined by eliminating duplicates, clarifying terminology. Ideas are then assigned to a category or bucket. Traditionally, this process occurs through the use of a facilitator, who leads the group through a discussion of the brainstorming ideas and prompts the group to categorize and organize the input. The end result is a set of organized ideas that are cleaner and easier to synthesize and process. What is interesting is how the group can reach end status. The means to this end was through the use of a facilitator, interacting orally with the group to categorize the ideas. While the brainstorming activities utilized parallel communication to expedite the ideation process, the categorization process typically does not. Group members must speak one at a time, like in traditional group work, so that the facilitator can guide the team during this activity. This difference between the parallel communication features of brainstorming versus categorization is echoed with the GSS feature of anonymity.

Anonymity refers to the GSS feature of having the interactions within a group meeting be anonymous (DeSanctis & Gallupe, 1987; J. F. Nunamaker, Jr. et al., 1991). Meeting participants can interact and exchange ideas without knowing who is responsible for which comments. Research identified several benefits associated with anonymous interactions in various stages of the group process (Connolly, Jessup, & Valacich, 1990; Diehl & Stroebe, 1987; L. M. Jessup, Connolly, & Galegher, 1990; Leonard M. Jessup, Connolly, & Tansik, 1990; J. F. Nunamaker, Jr. et al., 1996; J. F. Nunamaker, Jr. et al., 1991; Joseph S. Valacich, Dennis, & Nunamaker, 1992). These results indicate that anonymity allows ideas to be evaluated on their own, rather than who proposed them. This is especially important in very hierarchical or highly politicized organizations. Anonymity also allows for individuals to be more creative and to think of ideas that may be considered "out of the box" since there will be no negative social repercussions from suggesting these potentially innovative ideas in an anonymous environment. Anonymity leads to an improvement in the group process by reducing the process loss of evaluation apprehension (Gallupe et al., 1992; J. F. Nunamaker, Jr. et al., 1991). People feel less afraid to voice their ideas as it is an anonymous process. Evaluation apprehension is closely tied to one additional process loss, conformance pressure (J. F. Nunamaker, Jr. et al., 1991). In traditional meetings, participants may feel a certain amount of pressure to comply with the group or certain individuals of power within the group. In an anonymous GSS session, this pressure is reduced so that ideas and solutions are indeed evaluated purely in terms of their own merit without social pressures confounding the process.

As with the quality of parallel communication, the condition of anonymity depends on various contextual factors. As mentioned above, brainstorming is one scenario where the individuals are able to leverage anonymity to generate ideas to a given situation. However, if we look at the categorization process, we will see that this anonymity does not always hold true. When the group is using a facilitator to categorize the ideas, the interaction takes place orally. Oftentimes, questions arise as to the meaning of certain terminology or phraseology. Often, the facilitator will ask the group to define or resolve the ambiguity so that the idea is clear. The negative aspect of this interaction is that the original author may have to speak up to clarify the meaning, potentially erasing the benefits of anonymity and being linked to the comment. During this oral categorization process, participants must voice their opinion about which buckets are appropriate, which ideas belong in which buckets, which ideas are redundant, what the real meaning of certain ideas are, etc. These activities are typically not conducted through the use of a text-based computer system and are instead done orally, limiting the anonymity that is available to the participants. The ability of the GSS to provide anonymity and parallel work processing for the different collaborative activities is summarized in Figure 5.

| **Activity** | **Current GSS Functionality** |
|---|---|
| **Brainstorming**: | |
| • Anonymity | Yes |
| • Parallel work | Yes |
| **Categorization**: | |
| • Anonymity | No |
| • Parallel work | No |

Figure 5: GSS anonymity and parallel work features

The affordances of anonymity and parallel input create an environment where participants are more involved and able to contribute more to the meeting. In traditional meetings, Pareto's law applies (Brandt, 1995; Briggs, Ramesh, Romano, & Latimer, 1994-95; B.A. Reinig, 1996). This law states that fewer than 20 percent of the participants do more than 80 percent of the talking. In GSS meetings, people participate more evenly (J. F. Nunamaker, Jr. et al., 1991).

There are three additional process losses that GSS usage may actually increase as compared with traditional non-technology group work, free riding, information overload, and incomplete use of information. These three process losses are discussed in context of traditional group work versus GSS work then in context of the current research, PD-GSS.

Free riding is defined as individuals in group work not being actively involved in the group process as there are others in the group that will perform the work for them (Barki & Pinsonneault, 2001; Benbunan-Fich, Hiltz, & Turoff, 2003; Dennis & Valacich, 1993; A.R. Dennis & J.S. Valacich, 1999; Gallupe et al., 1992). The phenomenon is also known as social loafing in social psychology (Harkins & Petty, 1982). As the size of the group increases, the potential for having free riding increases as well. In a traditional, non-GSS meeting, it is much easier to see who is contributing to the meeting and who is not. However, in an anonymous GSS meeting, it is much more difficult to identify free riding, creating an incentive for group members to not be actively engaged in the group work.

One of the explanations for social loafing is that the members of the group feel unmotivated to exert substantial cognitive effort. This lack of motivation may stem from the fact that it is harder for their effort and contributions to be recognized or evaluated. The members may feel that their contribution is insignificant. The results of one review study in social psychology indicates that free riding is a pervasive phenomenon in group work but that it is not as likely to occur when the group members feel that the task or the group is important (Karau & Williams, 1993).

Some research has shown that the best way to address the problem of social loafing is through proper motivation (Shepherd, Briggs, Reinig, Yen, & Nunamaker, 1995). One researcher has suggested that it takes the "three C's of motivation" to get a group moving and reduce free riding: collaboration, content, and choice (Rothwell, 2004).

Collaboration, in this context, refers to assigning all group members to meaningful, special tasks to make sure everyone is involved. In a group systems context, this may not be a possibility during all collaborative activities, especially during convergence activities when work is not done in parallel.

Content refers to the identification of the importance of each individual's specific tasks within the group. If each member of the group feels that he is completing a worthy task or that the group will value the output, free riding will be reduced. In GSS groups, identifying specific tasks and values of those tasks is normally not feasible.

Choice allows the group members the freedom to choose the task that they would like to fulfill. Assigning individuals to tasks oftentimes creates tension and frustration. However, as group members are free to choose their task, the members feel more ownership and thus reduce the likelihood of free riding.

In a traditional GSS setting, each individual is normally not allowed the choice of which activity to choose nor is the identification of the importance of each task feasible. However, as will be discussed in later chapters, this research differs from traditional GSS in some of these regards. The current research allows participants to have some flexibility regarding which collaborative activities they would like to participate in.

Information overload is another process loss that can be exacerbated by the use of technology in a GSS collaborative session (DeSanctis & Gallupe, 1987; Hiltz & Turoff, 1985; J. F. Nunamaker, Jr. et al., 1991). It stands to reason that as a group is brainstorming via parallel communication, the number of ideas generated will be substantial. Research has shown that GSS groups generate more ideas than traditional groups that do not use electronic brainstorming software (A.R. Dennis & J.S. Valacich, 1999; Gallupe et al., 1992). Even though this increase in the number of ideas generated is considered a positive outcome of the group meeting, the information may be too voluminous and start to overwhelm the meeting participants. Each participant can generate ideas autonomously but all of these ideas must be read, comprehended, and synthesized by the rest of the group. It is unclear at what point the volume of brainstorming ideas would start to create an information overload problem. This research seeks to improve this process loss by controlling the rate at which brainstorming ideas are contributed.

The last process loss that we will discuss is that of incomplete use of information. This process loss works in tandem with the information overload process loss. If a member of a collaborative team cannot fully process all of the information from an information overload perspective, he or she cannot fully utilize all of the information available. Work by Dennis (1996) investigated this phenomenon. The study had two treatment groups. One group did not use GSS technology during a problem solving exercise while the other group did. The results showed that while the GSS group generated more ideas and more information than the non-technology group, the GSS groups did not use as much information for making their decision as the non-technology group. The findings suggested that perhaps the body of information for the GSS groups was too great to be utilized or that the format of the GSS tool itself limited the ability of the GSS groups to fully leverage all of the collaborative information. The workflow pattern of the current research project seeks to improve this process loss by enhancing the degree to which the collaborators are involved in the collaborative activities. This increased involvement promotes synthesis and comprehension of the information.

## 2.5. Contextual factors

The collaborative processes are impacted by the contextual factors of the group work. Two examples of these contextual features include synchronicity and proximity. Synchronicity refers to the timing with which group members interact with one another. Group work can be identified as either synchronous or asynchronous. In synchronous meetings, groups meet at the same time and discussion takes place in real time. These meetings are also known as "same time" meetings. It is important to note that synchronous meetings are not necessarily "same place". Synchronous meetings may be either proximal or distributed. Asynchronous group work consists of members of the team interacting at distributed time intervals. Participants can work collaboratively at differing times. Proximity refers to the degree to which group members are physically co-located or distributed during the meeting. Proximity may take many forms, ranging from every single member of the group being distributed, different sub-groups being distributed, to every member of the group being proximal. However, in general terms, GSS literature generally identifies both of these factors as dichotomous variables. The meeting is either asynchronous or synchronous as well as either proximal or distributed.

The lion's share of GSS research utilizes a synchronous and proximal approach. This is the most familiar setting in which a group is located in the same decision room, conducting collaborative work at the same time. The GSS survey study showed that of the 200 articles reviewed, 132 were conducted in a decision room (Fjermestad & Hiltz, 1998). This particular type of meeting has been shown to provide positive results, as the group is generally guided by a facilitator and individual participation is higher due to the same time, same place nature of the meeting.

The next type of meeting is a synchronous, distributed meeting. In these meetings, the group is working at the same time but the members of the group are, to some degree, physically dispersed. In these scenarios, members of the group can communicate exclusively through computer-mediated communication channels, including text-based channels (GSS, email, instant messaging), audio channels (teleconference or voice over IP), or audio-visual channels (video conferencing). Each of these modes of communication impacts the communication abilities of the group and subsequently the productivity of the group (Daft & Lengel, 1986; A. R. Dennis & J. S. Valacich, 1999).

The last type of meeting that we will discuss is the asynchronous, distributed meeting. In this scenario, the group is distributed physically and temporally. These types of meetings occur in settings where members of the group are widely dispersed geographically, rendering either a proximal or synchronous meeting not economically or logistically feasible. These types of meetings are similar to the synchronous, distributed meetings in that all communication must take place via computer-mediated channels. However, due to the asynchronous nature of the communication, the options are limited even further. For example, teleconferencing and voice over IP are no longer options, as these are synchronous means of communication. Likewise, live video conferencing is no longer a possibility. The group must use communication means that support asynchronous message exchange, such as voicemail, email, and text-based GSS. This further limitation in the communication channels reduces the abilities of the group to communicate effectively, potentially impairing the ability of the group to be productive. Likewise, the distributed and asynchronous characteristics create many challenges for meeting facilitators (Zhao, Nunamaker, & Briggs, 2002). Only sixteen studies of the 200 analyzed by Fjermestad and Hiltz used a distributed, asynchronous context (Fjermestad & Hiltz, 1998).

The proximity and synchronicity of the meeting alter the process flow, GSS design requirements, and the specific means that are available to the group to achieve their end goal (Turoff, Hiltz, Bahgat, & Rana, 1993). One example of this is in the categorization process that seeks to categorize the ideas generated during the brainstorming activity. As mentioned previously, in synchronous, proximal meetings the facilitator generally engages the group in a verbal discussion to identify similar brainstorming ideas and appropriately categorizing them. The means to categorization requires the use of verbal communication channels to interact and communicate with the group. Therefore, this approach to categorization can only be executed in the synchronous meetings where the audio channel is available for communication. In asynchronous meetings, or meetings that lack an audio channel, the facilitator cannot categorize the information in this manner. Other means to achieve categorization must be employed, including the facilitator categorizing the topics individually. This difficulty in categorizing the input from asynchronous groups is one of the improvements that the current research addresses.

One additional contextual factor that impacts the group processes and the methods employed to perform the collaborative work is the size of the group. The Fjermestad and Hiltz review of GSS studies indicated that the benefits of using GSS for group activities became more pronounced as the group size increased (Fjermestad & Hiltz, 1998). However, the largest groups reviewed in their study were composed of 24 individuals. Examination of the productivity of groups larger than 24 individuals was not included.

The size of the group impacts the ability of the group to achieve a productive outcome (Dennis et al., 1990). Ideally, as the size of the group grows, the percentage of the entire solution space utilized will increase proportionately (Gettys, Pliske, Manning, & Casety, 1987). However, as the size of the group grows past a manageable threshold, the collaborative group work becomes strained from multiple perspectives. First, as the size of the group grows, the GSS application must be capable of handling an increased volume of traffic and information. These increased demands on the application can tax the physical resources that the GSS needs (e.g., sufficient processing power or memory). Likewise, the GSS application must be written in a robust enough manner to handle numerous concurrent requests of the system. If the application is not properly coded or architected, the system will not be able to scale and properly handle the increased load from a large group.

Increasing group size also affects the collaborative processes as the volume of information may overwhelm existing collaborative approaches (Thorpe & Albrecht, 2004). New processes may be required to improve the utilization of increased information in an effort to minimize the potential for information overload and to increase the percentage of information that is utilized by the group.

Lastly, increasing group size presents numerous logistical challenges. These challenges include such things as economic, time, space, and computer resource issues. First, as the size of the group grows, the cost to execute the group work increases as well. This increase in costs is especially important in same time, same place meetings with individuals from disparate geographical locations. Travel and lost productivity costs could become prohibitive. Likewise, as the size of the group grows, finding a time that accommodates multiple schedules for a synchronous meeting becomes increasingly difficult. Trying to coordinate available times between the attendees may limit the ability to have a meeting or how often the meetings may occur. Larger groups also require increased meeting room space and access to computer resources. Space and computer resources may be prohibitive and limit the size of the group or the ability to meet as a group.

These examples illustrate the need for improved distributed, asynchronous collaboration. These types of meetings allow for individuals to participate according to their own schedule, reduce the logistical limitations, improve the potential to have collaborative meetings, and be able to harness the collective intellect of the larger group. These asynchronous, distributed meetings are increasingly important as the knowledge-based economy requires collaborative efforts to effectively address business issues. This is especially important as more and more businesses become global, distributing leadership and personnel over a wide geographic area.

# CHAPTER 3 – PARTICIPANT-DRIVEN GSS

The previous chapter outlined traditional GSS usage and the limitations of the existing GSS software and processes. This chapter outlines the proposed, new GSS framework called Participant-driven GSS, including the overall framework and specific modules.

## 3.1. Overview

The goal of the Participant-driven GSS framework is to leverage the skills and abilities of each of the group participants to further the collaborative work and accomplish the challenge the group set out to address. As the name implies, the participants themselves are placed in a position of increased responsibility and thus play an integral part in the collaborative process, providing the work and effort necessary to guide the group through the collaborative activities. PD-GSS seeks to leverage this knowledge base to improve the ability of groups to collaborate in a distributed, asynchronous environment.

There are two thrusts of the PD-GSS framework. First, PD-GSS seeks to improve the ability to collaborate in a distributed, asynchronous manner. This ability also leads to the ability to accommodate collaboration between larger groups. Second, PD-GSS seeks to improve the collaborative process by removing the facilitator bottleneck. This second thrust must be addressed in order to address the first thrust.

The name PD-GSS may imply that the facilitator is no longer needed or useful. However, PD-GSS still requires a facilitator or administrator of the meeting to make certain decisions regarding the workflow of the group. As was introduced in chapter 1, the goal of the PD-GSS system is to alleviate some of the load on the facilitator in an effort to enable more groups to be able to collaborate in the event that there is no facilitator available. This aim of PD-GSS is firmly aligned with the collaboration engineering research that seeks to empower the collaboration participants. These tools enable the facilitator or meeting participants to be able to effectively handle a potentially large, asynchronous, distributed group.

The facilitator or meeting leader is responsible for configuring and initializing the system. Administration of the PD-GSS workflow includes responsibility for setting various thresholds within the system as well as adjusting the volume of resources directed toward each specific collaborative activity, or module, within the overall collaborative workflow. The facilitator can adjust which modules are active and what percentage of users should be applied to the active modules.

One key aspect of the PD-GSS framework is that the framework seeks to improve the ability of the group to meet in an asynchronous, distributed fashion. According to Briggs et al (2003), collaborative engineering methods are in place that address the same-time/same-place collaborative meetings and that there is currently a void in support for distributed collaboration, especially with regards to convergence activities. The ability to effectively support asynchronous, distributed groups also enables the successful collaboration between larger groups than have previously been supported. The ability to work asynchronously also has additional benefits besides logistics and group size. Asynchronous collaborative sessions allow the users to further examine and analyze a given task, enabling broader discussion of the issues and alternatives (Benbunan-Fich et al., 2003). Others have posited that good ideas or insights occur not when someone is formally engaged in a brainstorming process or collaborative meeting but when the individual is performing his regular work (Robinson & Stern, 1997; Stenmark, 2001). Asynchronous collaboration allows the GSS tool to harness insight and ideas that occur outside the traditional GSS facility. Users can log into the system and contribute whenever inspiration strikes, regardless of time. The participants can analyze and develop additional insights and return to the GSS application to update or enter this new information.

## 3.2. Framework

Supporting large, asynchronous groups requires some modifications to the overall collaborative workflow and system architecture. Traditionally, GSS efforts follow a linear workflow similar to what was outlined in chapter 2. Essentially, the workflow is to identify the challenge for the group, brainstorm ideas or solutions, converge the ideas or solutions down to a manageable set of ideas, and evaluate and prioritize the alternatives. This sequence of divergence followed by convergence activities is the typical format that has been used in research and in field studies. However, PD-GSS seeks to alter the current paradigm. One of the features of this new framework is a dynamic workflow that allows for dynamic placement of individuals within various collaborative activities or modules within the overall group workflow. The end result is a set of activities within the overall workflow that can be engaged in a dynamic, iterative manner. To achieve this end, the system must be built in a manner similar to the

Collaboration Engineering model. Specifically, the overall workflow must consist of relatively independent building blocks or modules that can be iterated through as the group moves from beginning the brainstorming stages to the end, selecting action plans.

The modularity of the PD-GSS framework is similar to the notion of thinkLets within collaboration engineering (Briggs et al., 2003). Each module represents a basic collaborative activity that the group needs to complete in order to achieve the end goal of the collaborative efforts. The modular design is not only required for the dynamic workflow but it is also needed to enable an asynchronous workflow in a distributed environment. As the workflow takes place asynchronously, the ability and willingness of each participant to participate in the entire process from the beginning to the end is remote. Users may not be able to commit the time necessary to work with the group through the entire workflow. The user may be assigned to a different role within an organization or may be forced to allocate time elsewhere due to various demands. As a result, the system must be able to handle users working with the system at different stages. A user must be able to log in during different times during the overall workflow and provide whatever work is appropriate. In this manner, each user can contribute a little to the overall goal of the group achieving the desired end state. Figure 6 illustrates the overall dynamic, modular framework of PD-GSS, including users contributing and disparate times to the collaborative efforts. Instead of a sequential workflow, each module is able to be worked on in an iterative manner. Discussion of the specific modules will be presented in the next section.

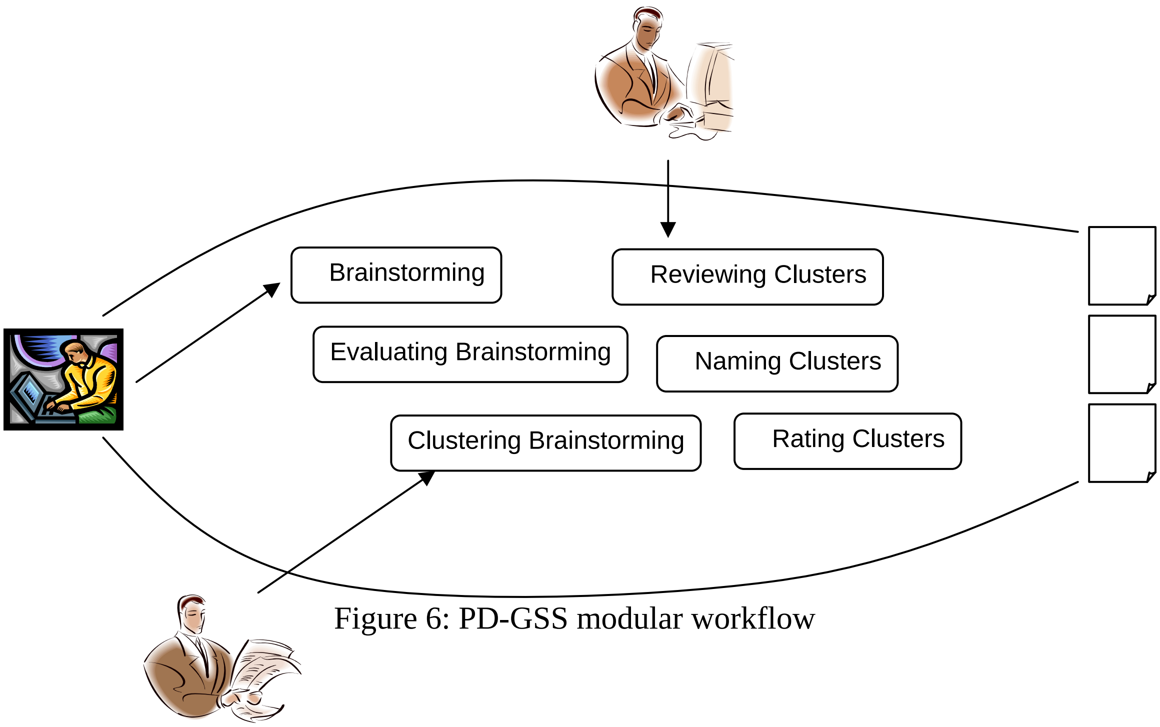


Figure 6: PD-GSS modular workflow

## 3.3. Sample modules

The following list outlines the sample modules from the PD-GSS framework. These are the same modules that are illustrated in Figure 6 above and represent a dynamic, modular collaborative workflow. These modules are as follows:

- Brainstorming
- Evaluating brainstorming ideas
- Clustering brainstorming ideas
- Reviewing clusters
- Naming clusters
- Rating clusters

The following section will describe each of the modules in additional detail, providing additional insight into the characteristics and benefits of these modules.

### 3.3.1. Brainstorming

The first activity within the PD-GSS workflow is brainstorming, similar to a traditional GSS workflow. However, within the PD-GSS framework, the divergence activity is controlled to improve the quality of the brainstorming ideas.

There are three major reasons for the need to control the brainstorming process. First, brainstorming typically allows each participant to enter ideas into the system at will. Due to the nature of the brainstorming environment, the level of quality of the comments varies dramatically (Hsinchun Chen, Houston, Nunamaker, & Yen, 1996). Figure 7 shows sample input from a brainstorming session. Between constraints on meeting time and individual differences in typing ability, comments can include numerous grammatical and typographical errors (#3 below). Likewise, the brainstorming input may contain ambiguous statements, unclear references, or incomplete ideas, hindering the ability of the other participants to successfully decode the meaning of the brainstorming input (#1-3 below).

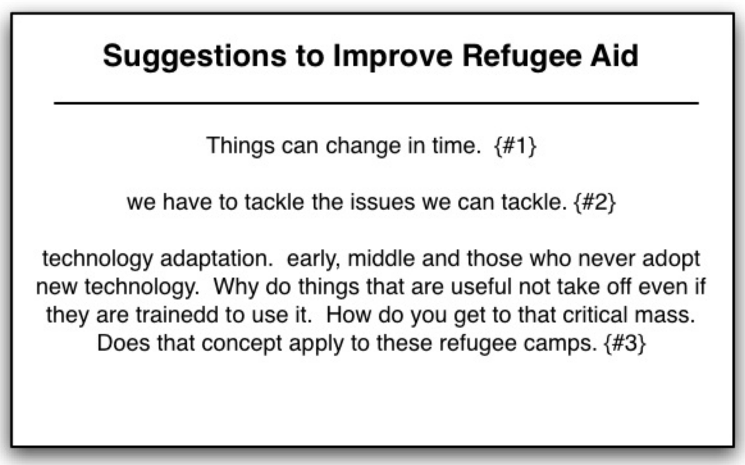


Figure 7: Noisy brainstorming input

The second reason is the size of the group. As the group size grows, the volume of ideas generated can grow geometrically. A group of ten to twenty participants can generate 500-1000 lines of input in one hour (H. Chen et al., 1994). This increase in the quantity of ideas implies that the number of low quality or noisy comments increases as well. The volume of these comments may impair the group process and require significant resources to resolve or clear up the comments. This is especially true within a distributed, asynchronous environment where communication between the collaborators is more limited than face-to-face, proximal meetings. The decreased ability to communicate effectively and efficiently may increase the time to resolve the issues during the synthesis process.

Finally, the output from the brainstorming activities represents the input into the convergence activities. As discussed previously, the convergence activities represent the more difficult activity to execute, for both the facilitator and the participants. To improve the convergence process, PD-GSS seeks to move “up stream” from convergence to the divergence process that provides the data. Improving the brainstorming input improves the input into the convergence activities and ultimately reduces the resources required to perform these activities. Less time will be required to examine, clarify, and resolve brainstorming ideas in the convergence stage.

PD-GSS seeks to have a set of brainstorming ideas or alternatives that are more coherent, complete, and concise. To achieve this end, all brainstorming ideas are subject to a peer-review process. Peer-reviewed Brainstorming is the notion that each idea must be edited and improved by random, anonymous peers within the group. The revisions conducted by the peers are performed in an effort to improve the quality of each brainstorming idea so that it is easier to read and process by the group.

The end result of the PD-GSS brainstorming design is to have a set of brainstorming ideas that has a higher concentration of quality content by reducing the quantity of “noisy” content (J. H. Helquist, Kruse, & Adkins, 2006a, 2006b). Traditional GSS research has focused considerable attention on improving the quantity of ideas generated during an ideation session. However, the link between quantity and quality of brainstorming is not definite (Briggs & Reinig, 2007). Research has shown that the causal linkage between quantity and quality indicates that there are other factors that influence the quality of the brainstorming output (Briggs et al., 1997; B. A. Reinig & Briggs, 2006). The PD-GSS framework posits that as group size increases, achieving a high number of brainstorming ideas generated is not a problem. As the size of the group grows, the number of ideas generated will grow exponentially. The problem shifts to enabling the collection of quality brainstorming ideas while reducing the amount of noise present. Limiting the volume of noise in the brainstorming ideas pool improves the ability to effectively manage the information, allowing for larger and larger groups to brainstorm. This notion of controlling the brainstorming process to improve the percentage of quality comments is illustrated in Figure 8 and Figure 9. Figure 8 illustrates traditional GSS brainstorming, which consists of a fair amount of noisy comments. Figure 9 depicts PD-GSS brainstorming that reduces the volume of noise while still collecting the valid ideas.

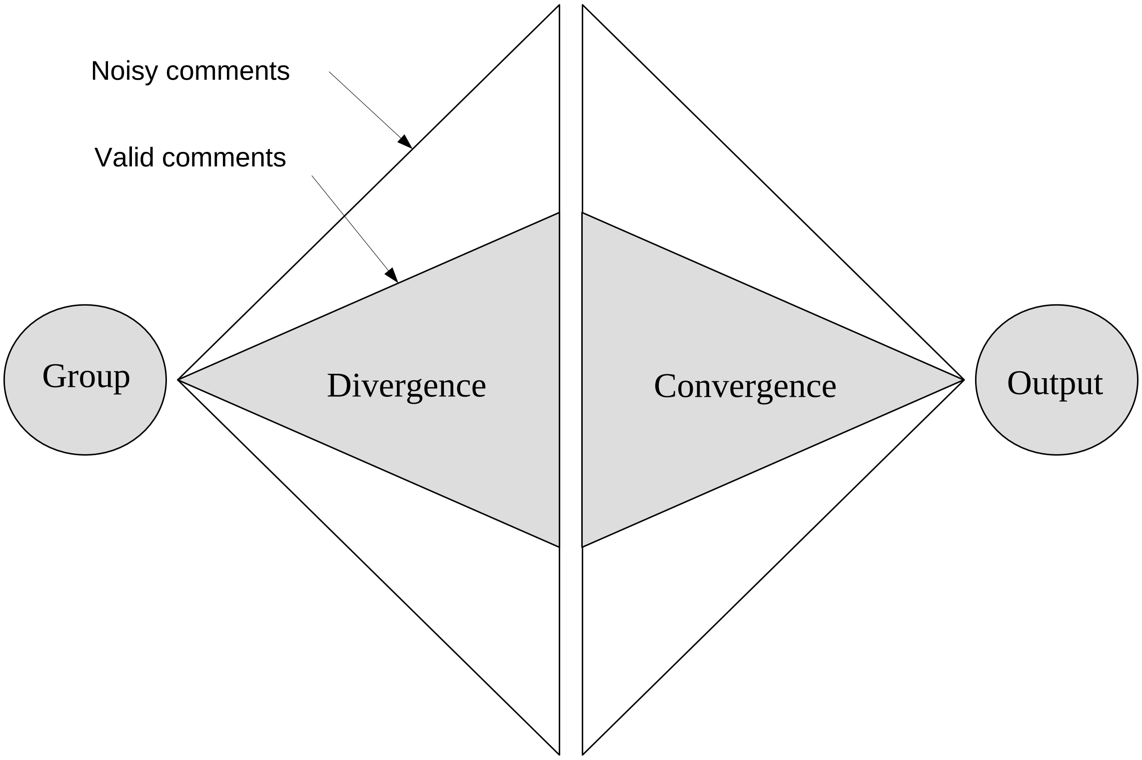


Figure 8: GSS brainstorming noise volume

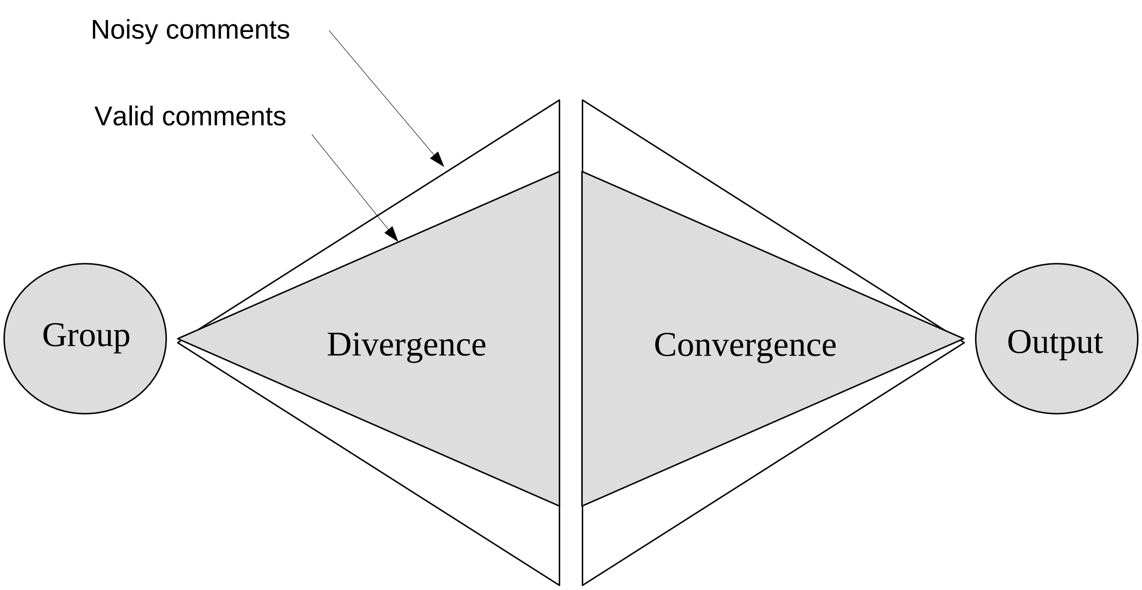


Figure 9: PD-GSS brainstorming noise volume

Traditional brainstorming includes a fair amount of comments that are either of low quality or no value to the group (e.g., off topic or non-solution comments). These ideas may consume enough group resources to constrain the collaborative process, potentially stifling the collaborative work (Briggs et al., 1997). However, the PD-GSS framework attempts to control this process to successfully gather the high quality ideas while limiting the quantity of noise.

The workflow for the Peer-review Brainstorming process is as follows. First, a new brainstorming input is entered and submitted by the original author. This new brainstorming input is submitted into a revision queue, where it waits to be reviewed by other participants within the group. As other participants have room in their own personal work queue, they are presented with the original comment and prompted to revise the original comment. The review process is based on framing, as outlined by Schwarz (2002) for face-to-face groups that Adkins and Schwarz (2002) have modified for computer-mediated environments. This framing provides instructions to the participant and prompts that guide the reviser to edit the original comment in such a way to render it more complete and coherent.

The original brainstorming idea and the revised versions are routed to another peer, who is responsible for selecting which option is deemed the best from the randomized list. Again, prompts are utilized to guide the participant to select the version that is the most clear and complete. The version that is selected as the best is then submitted to the overall brainstorming idea pool for the entire group to see Figure 10.

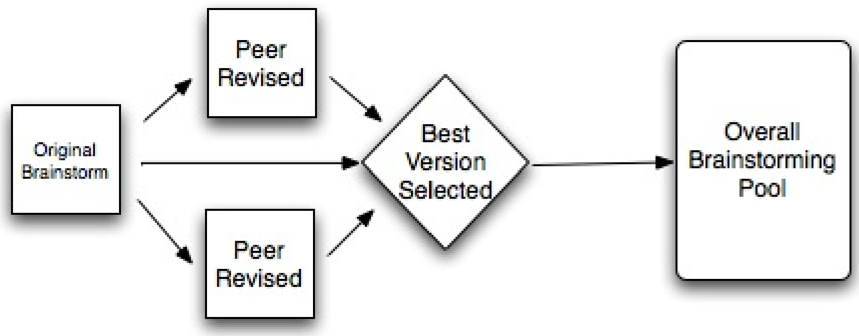


Figure 10: Peer-review brainstorming process

One of the features of this peer-review process is to incorporate additional, random peers from the group into the brainstorming process. Inclusion of three or more peers into the process helps to mitigate the risk that one individual may subterfuge the original brainstorming idea. With multiple people involved, the responsibility and ability of each person to undermine the overall idea of the original brainstorm is reduced. For example, if the original brainstorming idea contains a position that one reviewer does not agree with, he or she may be tempted to completely alter the original message in an effort to damage the original comment. However, additional peers will be reviewing the same comment, increasing the probability that the overall intent from the original message is still submitted to the brainstorming pool but in a more refined, polished format.

Requiring the participants in the group to be actively involved in reviewing the brainstorming ideas improves the comprehension of the input by the participants. The peer-review process increases the information processing and integration of the information by the participants as they are forced to read and edit ideas from their peers

(K. M. Hilmer & A. R. Dennis, 2000; Kelly M. Hilmer & Alan R. Dennis, 2000). Dennis (1996) found that even though GSS groups had access to more information, they were not likely to use or internalize that information. Explanations given for the lack of information processing include the lack of time to process all of the information, information credibility, and information saliency. PD-GSS provides more structure to the process, enabling the increased processing of ideas in the GSS session. Team Theory posits that participants' limited attention is a scarce resource that is required to access and process new information (Briggs, 1994). However, this limited attention is split between numerous requirements within a collaborative session. Peer-review brainstorming should improve information processing as the information is presented in a more refined, coherent state that allows easier access to the new concepts. Improving the quality of the brainstorming input allows for easier assimilation of the input.

### 3.3.2. Evaluating brainstorming

This module allows each of the participants to judge the quality or merit of each brainstorming idea. The evaluation of each brainstorming idea can be modified to have the members of the collaborative group judge each brainstorming idea according to whatever criteria the administrator or facilitator would like to utilize, depending on the context of the group's purpose. For example, the group may be asked to identify creative ideas to a certain problem. In this scenario, each member would be asked to evaluate all of the brainstorming ideas based on creativity. Likewise, the evaluation may include such dimensions as feasibility or ease of implementation.

In the PD-GSS framework, the evaluation of each brainstorming ideas plays multiple roles. First and foremost, the group can identify those ideas that considered of most value or those ideas that should be further reviewed or considered by the group, thus acting as a collaborative filter (Thorpe & Albrecht, 2004). These evaluations provide a mechanism by which to sort the brainstorming ideas. The sorting is of paramount importance so that the top ideas will bubble to the top and be easily read by the group while the lower rated items sink to the bottom of the list, garnering less visibility. This sorting is also of critical importance for later modules that deal with the brainstorming ideas on a meta-level, including the cluster reviewing and cluster naming modules. The brainstorming ideas that are rated the highest are selected and presented to each user as the representative sample; this sample selection presents one way to deal with large quantities of brainstorming ideas. This notion will be discussed further in their respective sections below.

It is important to note that the brainstorm evaluation activity is one that can occur in parallel with the brainstorming activity. Depending on the needs of the group, the facilitator may set the meeting up in such a way that users can rate the brainstorming input immediately as it is entered. Alternatively, the system may be configured in such a way to allow evaluation only after a certain amount of time has elapsed or a certain number of ideas have been generated. In the brainstorming activity, there may come a time when participants cannot identify any new solutions that could be contributed by the group. In these scenarios, the individuals either sit idly at their workstation or enter potentially low quality ideas or non-solutions into the brainstorming system. In a dynamic workflow, these users would be able to shift to other activities, such as evaluating the brainstorming input, when they are not able to generate new ideas.

One assumption of the PD-GSS framework is that the quality of the brainstorming ideas declines over the brainstorming period. Work by Helquist et al (2007) supported the idea that the quality of the brainstorming, as instantiated using creativity and feasibility ratings, decreased linearly over the duration of the brainstorming session. This research also supported the idea that the number of off-topic and non-solution brainstorming ideas increased linearly over the brainstorming period. These results provide support for the notion of having a dynamic workflow where users can participate in other activities, such as evaluating brainstorming, while the rest of the group stays engaged in brainstorming new ideas. Evaluating brainstorming ideas and brainstorming are two activities that can be run concurrently to potentially improve the efficiency with which the participants' time is allocated.

### 3.3.3. Clustering brainstorming ideas

The clustering brainstorming ideas module is the first of the convergence activities within the PD-GSS framework. The clustering module is similar to the categorize activity as discussed in Chapter 2. The clustering module allows the brainstorming ideas to be reduced and consolidated in such a way to allow the group to process the ideas, making the problem and solution space cognitively accessible. To achieve this end, the ideas themselves are grouped according to similar topics, categories, or threads. The end result of this activity is a set of categorized brainstorming ideas that allows the group to further address and investigate key ideas or issues that are identified. The clustering activity can be viewed as consisting of both convergence phase activity as well as an organize phase activity (Briggs et al., 2003).

In traditional, facilitated GSS sessions, the facilitator is responsible for working with the group to cluster and organize the brainstorming ideas. As discussed previously, it is during this process that the facilitator can clarify and distill the brainstorming ideas. In this manner, the facilitator can effectively deal with the "noisy" brainstorming ideas that are generated in the brainstorming process. However, as the group moves into a distributed, asynchronous environment and as the size of the group increases, these methods for categorizing the brainstorming ideas become either impractical or infeasible. If the group is asynchronous, the facilitator cannot communicate in a real-time, verbal manner to clarify meaning and organize the input. Likewise, the number of "noisy" comments may increase such that they become too large to be handled in a timely manner. It is possible that these difficulties could consume enough cognitive and technical resources to constrain the process, potentially stifling the ability of the group to find the best ideas (Briggs et al., 1997). As mentioned previously, these are some of the reasons why convergence is challenging, especially in a distributed, asynchronous session, as stated by Briggs et al (2003).

PD-GSS clustering seeks to address the problem of convergence through two distinct means. The first way to address the clustering problem is to control the divergence process, as discussed in the brainstorming module section. The output from the Brainstorming module is the input into the clustering brainstorming ideas module. By moving "upstream" and controlling the brainstorming process, the group can cluster and organize the ideas in a more efficient manner. The goal is to introduce a cleaner set of ideas as the input into the convergence activities such that fewer resources are required to perform the convergence activities.

The second means to enable clustering in the PD-GSS framework requires a significant change to the mechanism by which the clustering itself occurs. This change is necessitated by the differences in structural affordances between proximal, synchronous and distributed, asynchronous meetings. As mentioned, in PD-GSS meetings the facilitator cannot engage the group in a verbal discussion to conduct the convergence activity. Due to the asynchronous nature of the meeting, a different approach to clustering must be used. The PD-GSS clustering enables each participant to work in parallel and autonomously to move the group toward a final result of organized, categorized brainstorming ideas. The clustering module selects a sample of ideas from the brainstorming pool and sends this grouping to a given user. The user then has responsibility for making a judgment as to which items belong together in a cluster. This process is repeated numerous times so that each user can process various groupings of ideas, identifying similar ideas and generating a mapping of which ideas belong together. This distributed process can be viewed as a manual clustering process, leveraging the abilities and intellect of the participants to identify the logical groupings within the set of brainstorming ideas. The PD-GSS framework posits that the participants are better equipped to understand the correct level of detail and abstraction from which to consolidate and synthesize the brainstorming ideas than automated techniques. The participants are better able to deal with synonyms and "noisy" input that is harder for automated methods to address.

### 3.3.4. Reviewing clusters

The reviewing clusters module seeks to refine the clusters that were originally identified by the group during the cluster brainstorming ideas module. This module seeks to refine these clusters by performing two distinct but related tasks. First, the existing clusters are reviewed to determine if a given cluster needs to be split into two discrete clusters. Second, clusters are reviewed to determine if any need to be consolidated, reducing the number of clusters.

As with the original activity of clustering, this module is conducted autonomously and in parallel by the participants in the group. Both of the tasks, reviewing clusters for splitting or combining, requires that each participant be sent a random set of work to be processed. In the splitting review process, a random cluster is selected by the system and presented to the participant. The participant can review the items within the cluster to determine if the grouping is adequate or if a more specific, detailed clustering is needed that splits the existing cluster. In the combing cluster stage, the users are sent a listing of the clusters, with a sampling of the ideas for each cluster. At this point, the user is free to suggest the combination of various clusters to reduce the number of clusters and potentially increase the level of abstraction of the categories.

This module relies upon the rankings of each brainstorming input to allow for proper sorting when the system sends the random clusters to each participant. A given cluster may contain too many ideas and may overwhelm the participant if asked to review all of the items to determine if the items do indeed belong in one cluster. A sampling of the entire cluster must be selected and presented to the user; the sampling is based off of the users' evaluation of each brainstorming idea. The top brainstorming ideas are selected to be sent and displayed to the participants during this module.

The group can work autonomously but in concert to refine the categorization schema. The logical groupings of the brainstorming ideas will naturally begin to unfold as the users move toward equilibrium where group consensus is represented.

It should be noted that this module may not be necessary in the workflow and instead may be left to the discretion of the facilitator or meeting leader. The main purpose of this module is to converge on a proper level of abstraction for the categories. If the categorization includes categories that are too large and all inclusive, the group may need to move through a splitting process to further divide existing clusters into more detailed, specific clusters. Contrarily, if the categories are too detailed and too specific, the clusters may be too numerous and not worthwhile. In this scenario, the facilitator may wish to engage participants in consolidation efforts to increase the level of abstraction and to identify perhaps a better level of categorization. However, if the group initially identifies a logical grouping that is at a desired level of abstraction, the facilitator may not wish to devote resources to this activity.

### 3.3.5. Naming clusters

The next logical step within the collaborative process is to provide a name or label for each identified cluster. This name is intended to facilitate subsequent activities, including evaluation of each cluster as well as developing action plans and responses to the brainstorming ideas.

As with the previous modules, this module allows the participants to work in a distributed, anonymous fashion to develop adequate and appropriate names for each cluster. This is also an iterative process where the group first proposes a name for the group and then iterates through different alternatives until a specified level of consensus for a given name is achieved. In more specific terms, a few participants are sent a specific cluster and asked to develop an appropriate title for the cluster. Each user then submits the name and the list of potential names is started. These names are then sent to additional users, where each user can select one of the pre-identified names or can choose to enter a new name. This process is then repeated iteratively, with the system tracking which names receive consensus while eventually removing names that do not receive enough support. At the end, the name with the highest level of approval is then used as the label for the cluster. This threshold for consensus is a setting that the facilitator can adjust according to the specific circumstances of the group and their overall progress toward the stated objective.

### 3.3.6. Rating clusters

Similar to the previous module where participants rate each brainstorming idea, this module engages the participants to evaluate each cluster. The goal of this module is to rank order the clusters to identify the clusters that are considered the most salient or the most important. This evaluation occurs just like the previous evaluation module where the participants can evaluate the cluster as a whole based on whichever criteria the facilitator decides. This rating may be according to such topics as which category is the most important or which category provides the best return on investment.

Combined with the brainstorming evaluation module, this module provides the group with an outcome that can be prioritized either at the brainstorming level or at the category meta-level. This flexibility allows the group to better determine action plans and follow-up measures that are appropriate, depending on the circumstances.

It should be noted that the evaluation activities are not an iterative process at the individual level. Once a participant has logged his or her opinion, the vote is final and no additional votes by that individual are allowed. However, the facilitator may deem that additional iterations of evaluation are needed and may reset the evaluation activity. One example may be to re-prioritize the categories given only a subset of the clusters that were previously the highest rated. In this fashion, a facilitator or meeting leader may conduct iterative evaluations in an effort to focus the results and develop additional consensus within the group. Iterative rounds of evaluations have been shown to provide benefits to the group by focusing the discussion on salient issues, revealing areas of consensus or the lack thereof, and stimulating additional thinking (J. F. Nunamaker, Jr. et al., 1996; Pendergast & Hayne, 1995).

## 3.4. Potential intelligence of PD-GSS

The goal of PD-GSS is to enable the participants to collaborate more effectively and efficiently, even in asynchronous, distributed meetings. To this end, PD-GSS implements different processes and technology to address the limitations and challenges of distributed collaboration. As mentioned previously, the facilitator or meeting leader is still needed to make certain decisions and modify the settings and configurations of the PD-GSS session. These decisions the facilitator must make include either opening or closing a given module, and overriding the pre-programmed thresholds within the system. Advances in technology have created an interesting set of functionality that could further enhance the collaborative work and enable the more efficient use of participant's time within the group effort.

One key element of the potential intelligence of the PD-GSS framework is that the system itself has thresholds identified and set to automatically route participants to different modules as they log into the system. The system has the intelligence to understand where the group is within the overall workflow and can determine how many resources should be dedicated to which modules. For example, the brainstorming module may be configured to be active until there is a specified number of brainstorming ideas that are generated by the group. Likewise, the system may be set to monitor the rating of the brainstorming ideas and proceed to shut down the module when the ratings breach a given minimum threshold. Being able to automatically track the ratings of the brainstorming ideas and shifting users to different activities would lead to improved utilization of human resources and potentially a reduced volume of low quality brainstorming ideas.

One additional interesting potential for system intelligence is that of analyzing the behavior and productivity of the participants within the system. Specifically, there are two potential uses of this user activity analysis. First, a user may be so invested in a given topic that he becomes so involved to the point of starting to dominate a particular collaborative activity. To reduce the probability of this user exercising undue influence over the group process, the system could be configured to recognize the need to shift the user to a different activity or module within the overall workflow. Shifting the user to a different activity reduces the ability of the participant to dominate the group and potentially biasing the outcome of the group. Second, the system may profile members of the group to identify, quantify, and analyze their role within the group. This analysis could include such things as the number of ideas successfully submitted to the group during the brainstorming activity, the rating of the brainstorming ideas, etc. The system could use this profile to potentially assign different users to activities where they have been shown to be productive. For example, if a given user has not shown positive results during brainstorming, the user may be given the opportunity to shift to other activities where he or she may be better able to contribute meaningful work to the group.

## 3.5. Potential issues with PD-GSS

As with traditional GSS usage, there are a myriad of issues relating to the potential success or failure of the system itself. This section addresses these potential limitations and their impact on the system and the collaborative efforts. These issues require additional research efforts to further understand their implications and potential mitigating strategies.

### 3.5.1. Motivation and user involvement

One key area of concern with any distributed collaboration is that of user involvement. As previous research has illustrated, motivating the user to participate in the asynchronous, distributed collaborative session represents a major challenge that needs to be addressed (Briggs, Crews, & Mittleman, 1998; Romano et al., 1999). These concerns are especially valid within the PD-GSS framework as the requirements of each participant are increased. The users are asked to do more work than in traditional GSS sessions. As a result, the PD-GSS framework must balance the delicate issue of successfully engaging the members of the collaborative session by pushing more responsibility to them while not overloading and placing too much of a burden on them.

### 3.5.2. Limiting brainstorming solutions

The peer-review process that is utilized within the PD-GSS framework may limit the overall volume of quality ideas. Creativity may be negatively impacted by the controlling process, yielding a potentially less creative or less complete set of brainstorming ideas. The act of forcing participants to review brainstorming ideas may result in potential brainstorming ideas being stymied or forgotten. Likewise, the act of reviewing or selecting the best alternative may interrupt the creative processes of individual members and may result in a set of brainstorming ideas that is not as rich as would otherwise be obtained.

Previous research illustrated that group interaction can constrain idea diversity (Taylor, Berry, & Block, 1958). One of the reasons for this lack of diversity is cognitive inertia (Dennis et al., 1997). One of the dangers of PD-GSS is the potential to reduce participant input due to social comparison. “Members of brainstorming groups tend to compare their performance to others in their group and to match the rate at which they generate ideas to the rate at which they perceive others to generate ideas” (Dennis et al., 1997, p. 204). The potential impact of decreased social comparison is important to consider in both traditional GSS brainstorming and in PD-GSS brainstorming. Both of these scenarios limit the ability of a participant to gauge how much he or she is contributing to the group as well as how much other members of the group are contributing. These social comparisons may present a major issue with regard to individual levels of motivation and diversity of ideas generated (Tiwana & Bush, 2000).

Lastly, the act of performing the review process requires a time delay between when an initial idea is first drafted and when that idea, or a derivative of it, can be viewed by the entire collaborative group. This review process and the associated delay may yield substantially more duplicate brainstorming ideas than traditional brainstorming. As brainstorming ideas wait through revision queues before being submitted to the group, the same idea may be submitted various times by other participants. In traditional GSS brainstorming, the ideas are automatically displayed to the entire group, potentially reducing the quantity of duplicate ideas. These duplicates are of no value to the group and tax the limited resources of the group, namely time and human attention.

### 3.5.3. Lack of consensus

The entire PD-GSS framework is based on the notion of leveraging the skills and abilities of a group to gain the perspective and insight of a variety of people. The objective is to identify some level of consensus within the group, whereby the most salient issues, alternatives, or ideas are developed and identified. This notion of being able to identify some level of consensus or equilibrium is one of the key assumptions of this framework. However, when a group is assembled, it is possible that no clear consensus will be identified. This type of scenario leads to output that is of little or no value. Rather than enabling effective collaboration, the system would have enabled merely the aggregation of a variety of disparate points of view, leading to no clear conclusion or definitive action plan.

### 3.5.4. Lack of clear participant direction

One component relating to the gains in GSS usage is the importance of the directions and structure provided to the group (Adkins, Reinig, Kruse, & Mittleman, 1999; Lowry, 2002). This direction refers to the extent to which members understand not only the collective aim of the group but also how each individual's work contributes to the group's success. In traditional GSS sessions, the facilitator provides the necessary contextual information to the group, framing the overall problem, handling and managing the group workflow, and updating the group's status within the overall workflow. This contextual framing improves the saliency of the group work and the direction for the individuals and subsequently participant involvement. Clear, explicit directions are of utmost importance to the success of the group (Briggs et al., 1998).

However, the PD-GSS system, due to its asynchronous, modular nature, creates a workflow that is inherently more complex than a traditional, linear GSS workflow. The iterative nature of the PD-GSS session may confuse the individual, making it difficult to determine either the value of his or her individual contribution or the status of the group and its progress toward the stated objective. These factors reduce the contextual framing for each participant and the direction process gain. This reduction in direction may contribute directly to low user involvement, free riding, or reduce the quality of the group outcome due to misunderstanding.

## 3.6. Prototype development

Research within GSS shows that GSS tool design should include certain features or properties. This section discusses some of these attributes.

### 3.6.1. Modularity

The first characteristic identified within GSS research is that of a modular system design (J. F. Nunamaker, Jr. et al., 1991). Modularity within the GSS enables the system to be configured in a variety of ways depending on the context of the group. This flexibility is paramount as each collaborative process is different, requiring different collaborative tools to be used at varying times within the overall workflow. As stated previously, this modularity coincides with the motivation behind thinkLets. Modularity also improves the development process of the software itself as components are able to be reused, reducing the total time to successfully code the GSS tool (Parnas, 1979).

This modular design is represented in the architecture of the PD-GSS system and one of the prototype modules that was developed to examine the feasibility of the PD-GSS brainstorming approach. One collaborative module, PD-GSS brainstorming, was developed and examined. A second module, group cluster, is also discussed and potential prototypes are examined. The discussion of these modules and the examination of each are discussed in later chapters.

### 3.6.2. Short learning curve

A short learning curve is needed for the participants to not feel overwhelmed and to be productive in a short period of time after a brief training (Briggs, 1994; Briggs & Vogel, 1994; Dean, Lee, Orwig, & Vogel, 1995). The interface design chosen for the implemented module embraces this philosophy. The interfaces are implemented in a simplistic fashion, minimizing potential interface confusion by improving the intuitive nature of the module.

### 3.6.3. Prototype requirements

To implement a distributed, asynchronous system requires certain system characteristics. First and foremost, the application needs to be a web-based support tool in order to minimize the requirements for participating in the group collaborative session. A web-based application has the following benefits (Albrecht, 2003):

- Platform agnostic - Web-based applications allow a participant to collaborate with the group regardless of the operating system he or she is using. The thin-client browser eliminates the dependence on any one given platform or the need to create different versions of the GSS tool that can operate on different platforms.
- Minimal system requirements - The only requirement to participate in the web-based collaborative session is a web browser. No special plugins or Java virtual machines are required to collaborate. These requirements lower the technical threshold to participate in the collaborative group. These light requirements also

mean that older and slower hardware is able to work with the collaborative tools as well.

- Centralized software - The PD-GSS tool is centrally located on one server. The participants do not need to load any special client software on their workstations. As a result, software updates are easier to rollout as the software only needs to be updated in one location. Client applications do not need to be updated.

## 3.7. Prototype architecture

Based on the requirements stated above, the prototype module developed in this research project was built using the GroupMind framework. GroupMind is a groupware application written by Dr. Conan Albrecht that uses DHTML to dynamically handle collaborative sessions. It is an event-based web development platform that allows for web-based collaboration. GroupMind is written in Python and builds upon the idea of having modularized components.

One module was selected to be prototyped to examine the feasibility of the PD-GSS conceptual idea, peer-review brainstorming. This module was selected since it represents the first logical step in a collaborative process. Also, a vast amount of brainstorming research has been conducted regarding brainstorming productivity.

The peer-review brainstorming module also has an associated administration component within the GroupMind administrator interface. The administration component allows the facilitator or meeting leader to set various parameters or thresholds that are essential for module.

## 3.8. PD-GSS roadmap

The PD-GSS framework presented in this chapter represents a big picture framework of where this line of research is moving. The ultimate end goal is a complete, detailed framework with a full working system built on this framework. However, the development of an entire instantiation of this framework is outside the scope of this dissertation. This research is concerned with presenting the framework and providing an initial examination of the feasibility and effects of the system. This research represents the first initial steps in the exploratory investigation into a new type of GSS system. This research examines the first two modules. Subsequent research will examine additional modules as additional components of the PD-GSS system are developed and tested.

Lastly, it should be noted that the experiments within this research are synchronous and proximal. As stated previously, the ultimate goal of this framework is to enable asynchronous, distributed collaboration. However, to simplify the first, pilot examination, this research examines these modules in a same-time, same-place setting. This experimental setting reduces potential confounding issues, allowing increased focus on the PD-GSS process and tools. Subsequent research will examine and compare varying temporal and geographic dispersion as the PD-GSS research life cycle matures.

## 3.9. Module discussion

This section presents an overview of the specific implementation of the PD-GSS brainstorming module prototype and discussion of further analysis regarding the categorization module. Previous research approaches are discussed that relate to each of these modules.

### 3.9.1. Peer-review brainstorming

The first module implemented in a prototype is a divergence module called peer-review brainstorming. As stated previously, this module controls the brainstorming process by engaging group participants to edit and update brainstorming ideas to improve the clarity and cohesiveness of the brainstorming ideas.

The module was coded in such a way that each new brainstorming idea is added to the data tree, waiting for a participant to review the brainstorming idea. The idea is then routed to two random peers for review and editing. Each of these additional versions of the original comment is added to the original comment data element in the tree. At this point, the comment is ready to have the best version selected. Another random peer is selected to select the best version from the three. At this point, the data element is updated to indicate that the best version has been chosen and which option was selected as the best. The best version is then made available for the entire collaborative group to view. Screenshots of this module and the associated process are shown in Appendix A.

In the administrative options, there are two key parameters that are used to control the brainstorming module. First, the module allows for the facilitator or administrator to set the number of revisions each original brainstorming comment must have. This is an important parameter that should be set in accordance with the size of the group. As the size of the group increases, the facilitator may wish to increase the number of revisions each brainstorming idea must go through. It is posited that as the number of revisions is increased, the potential quality of the best alternative selected is increased. Likewise, as the number of revisions increases, the dependence on any one individual is decreased.

The second parameter allows the facilitator or administrator to determine the threshold when each participant can enter a new brainstorming idea or when the participant must review previously entered by a peer. This setting allows the facilitator to determine the quantity of items in the queue that need to be reviewed. For this prototype, the parameter is set to two. When the number of items in the revision queue exceeds two, the participants are forced to review items in the queue.

**Previous Attempts**

Examination of the literature reveals that previous attempts have been made to handle brainstorming in a large group setting. This section reviews some of these approaches and their limitations as compared with the peer-reviewing mechanism.

The first set of literature takes the approach of attempting to automate the brainstorming control process. The first group of these papers seeks to leverage system technology and linguistic analysis to improve the brainstorming process (Adkins, Kruse, & Younger, 2002, 2004; Adkins & Schwarz, 2002; Lopez, Booker, Shkarayeva, Briggs, & Nunamaker, 2002). One approach, proposed by Adkins et al proposes a natural language processing approach to monitor the brainstorming ideas entered into the system. The facilitator of the group can setup certain linguistic rules that entries on the GSS tool must abide by. These rules are considered ground rules that help the group abide by specified core values of the group. The system performs constant monitoring of the brainstorming ideas and alerts deviations from the prescribed rules. This approach provides the facilitator with improved, automated capability to improve the quality of the brainstorming ideas. This type of computer-generated feedback is similar to existing GSS research that shows the benefits of automated cognitive feedback during the workflow (Sengupta & Te'eni, 1993).

These automated approaches rely heavily on linguistic analysis and natural language processing techniques. While these linguistic techniques reduce the amount of human labor required and are highly scalable, the techniques are not as advanced as need to be to fully understand the complexities and the context of brainstorming ideas. Agent technology cannot generalize or refine terminology that participants in the group are able to do. The participants are better equipped to clarify, refine, and upgrade brainstorming ideas. Additionally, development of specific ground rules for the group may not be entirely possible or may be too complicated to be used effectively.

The second approach to handling large groups does not utilize linguistic analysis but uses the capabilities of the participants, like PD-GSS. Research by Faieta et al (2006) presents an idea of a scalable brainstorming process that can accommodate large groups. The notion behind this approach is that brainstorming ideas are entered into the system and rated by the group. The key part of this approach is that the brainstorming idea is first rated by a small sub-group within the whole collaborative group. Ideas that are rated highly are then circulated to larger and larger groups as long as the ratings stay high. The end result is that only highly rated ideas are seen by the entire group while ideas that are not rated highly are only seen by the small group. This mechanism attempts to harness the quality ideas while minimizing the cognitive overload of having a large group of individuals generating ideas.

While PD-GSS and this approach both leverage the capabilities of the participants themselves, this approach does not appear to easily handle asynchronous, distributed groups or collaborative sessions where participants are not able to participate for the entire duration of the session.

### 3.9.2. Group cluster

The second module analyzed during this research is the first convergence module called group cluster. This module allows the participants to categorize and organize the brainstorming ideas into buckets. This approach engages each participant to randomly work through a selection of brainstorming ideas, identifying those ideas that belong together in the same category. Individuals continue to receive a set of random ideas and identify ideas that belong in the same category for the duration of the categorization process. The system tracks each association between ideas that are identified by the participants. The end result is a set of ideas that are clustered by the group in a manual, autonomous fashion. The administrator is able to view an output showing each brainstorming idea and the ideas that were identified as being associated with the idea.

The administration of this module will contain one important setting for this clustering activity. The facilitator can determine the number of brainstorming ideas that are randomly selected and sent to participants throughout this activity. Larger sizes allow the participant to view a larger selection of ideas, providing more context against which to make the judgments. However, larger sizes may overwhelm the participants as there is additional information that must be read and processed at a time.

**Previous Attempts**

Previous work in this area has focused on providing an automated clustering mechanism to group similar brainstorming ideas (Hsinchun Chen et al., 1996; H. Chen et al., 1994; H. Chen, Nunamaker, Orwig, & Titkova, 1998; R. Orwig, Chen, Vogel, & Nunamaker, 1996; R. E. Orwig, Chen, & Nunamaker, 1997; D. Roussinov & Zhao, 2003; D. G. Roussinov & Chen, 1999). This body of research leverages artificial intelligence algorithms to automatically cluster the brainstorming ideas, reducing the time to categorize and organize the ideas. The work is promising but as stated previously, artificial intelligence techniques are not yet sophisticated enough to handle the complexities of categorizing the brainstorming ideas. As Chen et al (1996) state, the automated solutions still need work with regard to the level of abstraction of the clustering as many categories are too general. The system also lacks the domain specific knowledge to provide the proper level of abstraction in creating the clusters. Interesting work is currently being performed to enhance the automated abilities. One such effort is to improve the system's understanding of synonyms. Research by Roussinov and Zhao (2003) presents an interesting approach to creating a thesaurus to improve clustering results. This work leverages the World Wide Web to compile a repository of words that appear together, thus approximating the functionality of a thesaurus. However, PD-GSS posits that, at this time, participants are better able to understand the level of detail and the context within which the brainstorming ideas were entered.

# CHAPTER 4 – METHODOLOGY AND DESIGN

Chapter 3 presented the overall framework and roadmap for the PD-GSS architecture.  This chapter presents the design and experimental methods employed to investigate and further examine PD-GSS.  This chapter provides details concerning the experimental procedures, data collection, and data analysis techniques used for the two laboratory experiments in this research.

## 4.1. Chosen research methodologies

A multi-methodological research approach was utilized for this research.  This approach is based upon a systems development and engineering approach.

### 4.1.1. Systems development

This research project is largely exploratory in nature.  It has been guided by the principles of a systems development research methodology (J. F. Nunamaker, Jr., 1992; J. F. Nunamaker, Jr., Chen, & Purdin, 1990/91).  Systems development research is an engineering type of approach to investigating IS phenomena by building and evaluating an IT artifact (Orlikowski & Iacono, 2001).

Nunamaker et al state that this IT artifact is the bridge between technological research, also called the "concept" stage, and the social research, which they refer to as the "impact" stage.

Systems development plays an integral part in fully understanding the development and use of information systems in business contexts, which is the goal of

MIS research. In order to understand concepts that are as complex and dynamic as Group Decision Support Systems, researchers need a multi-methodological approach to investigate and analyze the wide variety of issues associated with the research question (Vogel & Nunamaker, 1990)

This multi-methodological research approach, as represented by Nunamaker et al., is presented in Figure 11. Systems development is an integrated approach to IS research, consisting of four research strategies: theory building, experimentation, observation, and systems development.

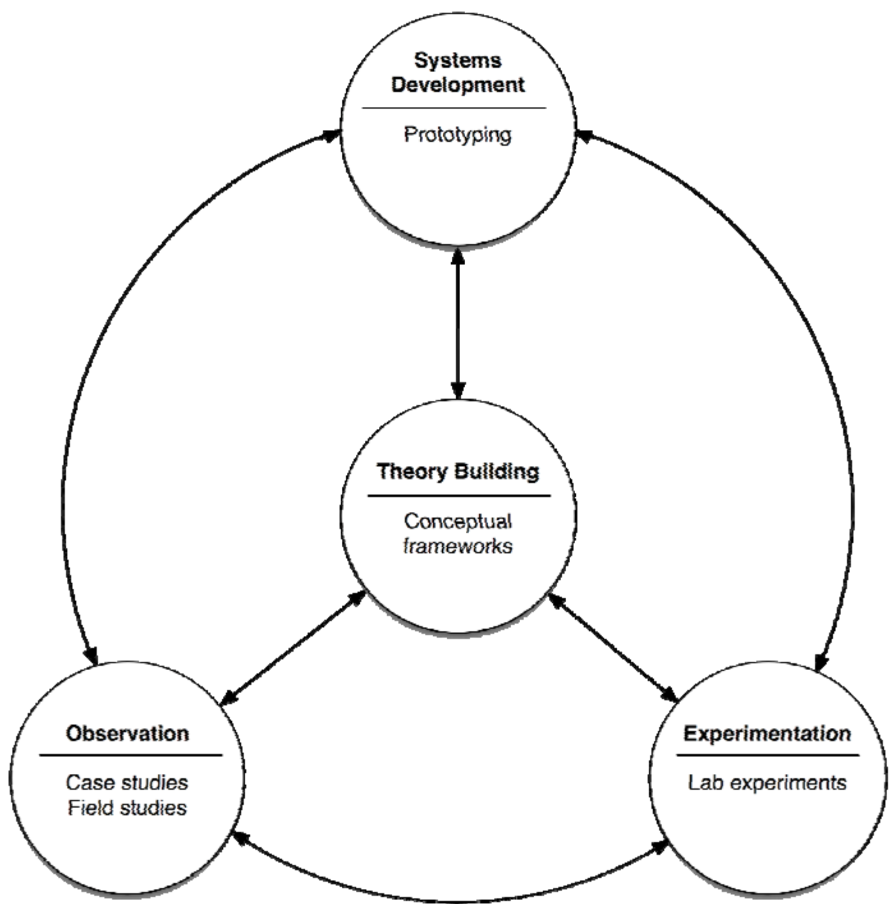


Figure 11: Systems development multi-methodological research approach

Theory building is defined as the development of new ideas, approaches, or conceptual frameworks. Most research projects start with a research question that is based upon theory or from which a theory is built. According to Nunamaker (1992), "theory building in MIS both supports and is supported by systems development, and is both a precursor for and an outcome of experimentation and observation" (p. 3). The theory drives the development of a specific system, which is in turn evaluated, providing feedback to refine the original theory.

Experimentation is the investigation of hypotheses or research questions that are based on theory, using research strategies such as laboratory and field experiments. This step can be viewed as the validation of the underlying theories (J. F. Nunamaker, Jr., 1992). The experiments themselves are guided by the theory but require the use of an IT system, as facilitated by systems development. The experimentation provides analysis that guides the refinement of theories and the improvement of information systems.

Observation seeks to improve the generalizability of the research by investigating the system and its use in a natural setting within a specific domain. Observation can take place via case studies, field studies, and sample surveys. The results from these types of strategies provide data that also further refines the information system.

Systems development is an integral part of the multi-methodological research approach that ties the previous three strategies together. Systems development is an integral part of the research, creating an integrated, dynamic research program (J. F. Nunamaker, Jr. et al., 1990/91). As stated by Nunamaker et al, "this approach is equivalent to a proof-by-demonstration" (p. 91).

This research utilizes three of the four methodologies of this multi-methodological framework. First, the PD-GSS framework is conceptualized. The analysis of the requirements and architecture needed for the prototype system are developed. This framework is utilized to prototype one of the collaborative modules. Lastly, lab experimentation is conducted to further understand and refine the PD-GSS framework and the prototype module.

The systems development methodology contains five stages: concept design, constructing the architecture of the system, prototyping, product development, and technology transfer (J. F. Nunamaker, Jr., 1992; J. F. Nunamaker, Jr. et al., 1990/91). These stages are illustrated in Figure 12 below.

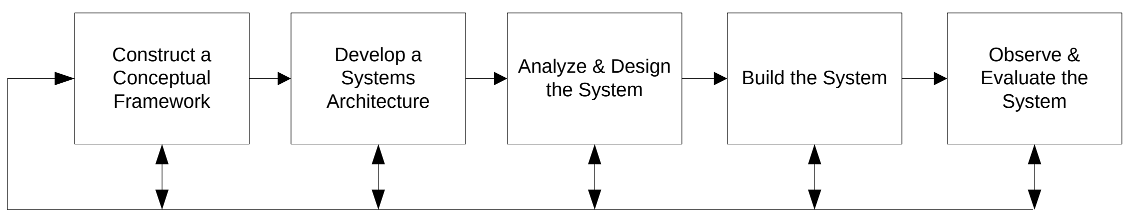


Figure 12: Systems development stages

## Construct a conceptual framework

The conceptual framework is the start of a new research project. This stage consists of stating the research questions and what the objectives of the research are, providing a relevant framework that will guide the development process.

**Develop a systems architecture**

The systems architecture is the blueprint for developing first the prototype and full system. In this stage, the functionalities and the requirements of the system are defined.

**Analyze and design the system**

This step deals with the identification of the potential solutions and identification and selection of the best scenario. In this step, analysis is conducted to determine the database design as well as the processes to carry out system functions.

**Build the prototype system**

This stage involves the instantiation of the architecture and the design into a functioning version of the system. This prototype enables the researcher to further understand the issues involved.

**Observe and evaluate the system**

This stage involves the rigorous investigation of the impacts, performance, and use of the system within a given context. This evaluation provides the required information to guide the refinement of the theories, conceptual frameworks, and the prototypes themselves.

## 4.2. Analyzing the research question

The research question in this project is: can an improved GSS system be built that could accommodate asynchronous, distributed groups? It was analyzed by different methods. First, the research question drove the development of the PD-GSS framework, a conceptual framework for investigating the research question. This conceptual framework was presented in Chapter 3.

Second, a prototype system module was developed to present a proof-of-concept in accordance with the systems development methodology. This prototype development followed the five stages of system development listed above. The module and its development were discussed in Chapter 3.

Lastly, the prototype module was investigated further in a laboratory experiment. A second experiment was performed to investigate the design considerations of a second prototype. The purpose of this experimentation was to further refine and improve the conceptual frameworks and processes associated with PD-GSS rather than to test strict hypotheses. The methods and experimental designs for these experiments are discussed next. The results for these two separate experiments are presented in Chapter 5 and discussed in Chapter 6.

## 4.3. Experimental task

The two experiments conducted as part of this exploratory research into PD-GSS utilized a closed-ended, hidden profile task. This task, the school of business task, presents a hypothetical school of business at a large, public university that is facing various challenges (Mennecke & Wheeler, 1993). These challenges include such things as poor physical resources, problems with instructors, untrained teaching assistants, and declining enrollment problems. The subjects were tasked with identifying recommendations to improve the issues that the school is currently facing. The school of business task is closed-ended in that all of the symptoms from the school stem from one source, which is obscured from the subjects. For the full text of the school of business task, see Appendix B. This task was selected because it provides the subjects with a domain and task with which they are comfortable and possess some experience with. The subjects could relate to the problems of the school of business, improving their level of motivation and desire to provide valuable solutions.

## 4.4. Experiment 1 – divergence task

The first experiment examined the prototype PD-GSS, peer-reviewed brainstorming, divergence module. The experiment compared traditional GSS brainstorming to PD-GSS brainstorming to examine the impacts of the more refined, controlled brainstorming process. This pilot study serves as an exploratory examination into the impacts of the new brainstorming process, providing the feedback and information necessary to tailor the peer-review process and the means to obtaining a higher quality set of brainstorming ideas.

### 4.4.1. Subjects

Subjects for this first experimental task were recruited from the honors section of the introductory Management Information Systems class in the Eller College of Management at the University of Arizona. The subjects were given course credit for their participation in the laboratory experiment. Sixty-seven subjects participated in this experiment; fifty-seven percent of the subjects were female with the average age of the subjects being 18.21 years.

### 4.4.2. Treatments and independent variables

The subjects worked together in groups of 6-7 to brainstorm solutions that would fix the school of business. The average size of the group was 6.7 subjects. The size of the groups was selected for two reasons. First, it represents a smaller sized group that has been used in considerable research (Fjermestad & Hiltz, 1998). Second, six represents approximately the smallest size group that can successfully perform the peer-review brainstorming activity, given that each brainstorming idea must be reviewed and edited by two peers and a third peer must select the best option. Groups smaller than six subjects may not provide enough human resources to enable successful brainstorming in this manner. This pilot study utilized the smaller groups in an effort to maximize the number of groups that could be accommodated in the GSS laboratory.

Two treatments, described below, were utilized during this pilot experiment, with each treatment consisting of five groups. Subjects were randomly assigned to experimental groups during the check-in process for the experiment. Both treatments were tasked with utilizing GSS tools to brainstorming electronically for a period of twenty minutes.

**Free brainstorming**

Free brainstorming represented the control treatment. This treatment consisted of a traditional brainstorming environment where each participant was free to brainstorm at will. The participants in this treatment used a traditional GSS brainstorming module as previously implemented in GroupMind. In this module, the subjects could brainstorm freely using the web-based GroupMind, in an anonymous, parallel fashion.

This traditional brainstorming imposes no restrictions or reviews on the ideas that are entered. For this reason, subjects can enter whatever comments, critiques, or off-topic comments, despite the specific instructions to enter valid brainstorming ideas.

**Peer-reviewed brainstorming**

The treatment groups brainstormed using the modified brainstorming module based on the peer-reviewed framework. In this manner, groups could brainstorm but each brainstorming idea was processed through the peer-review system before the idea was accepted and shown to the entire group.

This module was configured as described in Chapter 3. Each brainstorming idea was subjected to two random peers, who then were able to edit, modify, and create their own version of the original brainstorming idea. The resulting three versions of the brainstorming idea were then routed to an additional, random peer for selection of the "best" alternative. As a result, four members of the group were responsible for some phase of the review process for each of the brainstorming ideas generated by the group. The module was coded in such a way that no one subject could assume more than one role during this process. Likewise, it should be noted that all of the review process is conducted in a completely random and anonymous manner.

### 4.4.3. Research questions

The objective of the experiment was to further understand the impact of the peer-review process on the group as compared with traditional, free brainstorming. Due to the exploratory nature of this research, no formal hypotheses were tested. The following research questions were posed as part of the research:

1. Does the peer-review process limit the quantity of noise?
2. Does the peer-review process limit the quality of ideas generated?
3. What is the impact on the number of valid ideas generated?
4. What are the impacts on the number of high-quality ideas?

5. What are the impacts on participants' satisfaction with the process and the results?

**4.4.4. Procedure**

Subjects were randomly assigned to one of the treatments upon arrival at the experimental laboratory, as described in the treatments section above. The subjects were given their unique login information, which determined group membership. The subjects were placed into groups of 6-7 subjects and could sit randomly at one of the computer workstations within the GSS room. None of the participants knew which participants comprised which group. The interaction was conducted in an anonymous manner through the GSS.

The laboratory facilitator read from experiment's script to ensure consistent delivery of the instructions and experiment setup, see Appendix C. At the start of the experiment, the subjects were asked to read and accept the consent form and asked to read the school of business task. After reading the task, each subject completed the demographic questionnaire. The subjects were then provided a demonstration of the brainstorming tool and questions regarding the case study and the tool were clarified and resolved.

The participants were then given twenty minutes to do the brainstorming according to the respective treatment. The subjects were given prompts when there were five minutes left and one minute left. They were also asked to provide quality ratings for each brainstorming idea that the group surfaced. The subjects were free to provide ratings at any time during the twenty minute brainstorming session. The specifics of these quality ratings will be discussed further in the Dependent variables section that follows.

At the conclusion of the brainstorming session, the participants were each asked to complete a questionnaire regarding their experiences. The specific questions on the survey were derived from previous literature on brainstorming and GSS usage (Briggs & Vreede, 1997; Dennis, 1996; Santanen, 2002; Santanen, Briggs, & Vreede, 2004), see Appendix D. After completion of the questionnaire, the subjects were thanked and dismissed from the GSS room.

**4.4.5. Dependent variables and data collection**

The GSS tool, GroupMind, automatically captures and records the brainstorming ideas and associated ratings within its own data structures. Scripts were written to extract this information for further statistical analysis. Scripts were also written to extract details about the peer-review process. In the control treatment, the following information was retrieved from the system: brainstorming ideas and quality ratings. For the treatment condition, the final idea selected as the best and the associated ratings were gathered, as well as which subject generated the best idea.

The quality ratings were composed of two different ratings, creativity and feasibility. These ratings were based on previous literature of brainstorming quality that utilized an overall quality metric that incorporated these two dimensions (Barki & Pinsonneault, 2001). This research does not argue that these dimensions are all encompassing. Additional dimensions have been proposed, including the effectiveness of the idea (Barki & Pinsonneault, 2001). Creativity refers to the degree to which the idea is novel or original while feasibility refers to how easily the idea can be implemented (Diehl & Stroebe, 1987).

The participants were responsible for performing the quality ratings themselves on Likert-style scales from 1 (low creativity, low feasibility) to 5 (high creativity, high feasibility) for each of the dimensions. For the purpose of this experiment, the quality ratings were not in and of themselves the most important measure. Additional emphasis was placed on the quantity of valid ideas.

Valid ideas are defined as ideas that are on-topic and are not duplicates. All off-topic, non-solution, and duplicate comments were removed from the data set, yielding original, appropriate comments. Off-topic comments include any comments that do not directly relate to the experimental task (e.g., “I’m tired of brainstorming”). Non-solutions include comments that do not present a solution to the task but are germane to the task (e.g., “I agree” or “Please clarify that comment”). Lastly, the duplicate ideas refer to the number of comments that replicate an idea that has already been presented. The number of valid ideas was calculated for each group in the experiment.

Lastly, subjective self-report measures regarding satisfaction with the process and the results were gathered via the post-survey. These results were analyzed to understand the impacts of the peer-review process on the overall satisfaction of the subjects.

## 4.5. Experiment 2 – convergence task

The second experiment conducted as part of this research examined the design and ramifications of the convergence module. For this experiment, a specific PD-GSS prototype module was not implemented for examination. Instead, an existing GSS installation was used to examine various contextual factors regarding the categorization process. The results of this initial exploration serve as the foundation for theory refinement, prototype development, and further examination.

There currently exists a dearth of research concerning the convergence process in the literature. Accordingly, previous literature on which to base the module prototype and associated experimentation is not sufficient to form an appropriate foundation for this research. This research seeks to initiate the development of this theoretical and empirical foundation of literature to further guide and refine convergence research. As has been stated previously by Jay F. Nunamaker, Jr. regarding collaborative research, an adequate level of experience must be obtained to understand the problem domain sufficiently in order to ask the correct questions (J. F. Nunamaker, Jr., 1997; Romano et al., 1999)

The primary purpose of this research was to further understand and examine the ability of groups to conduct convergence activities without the aid of the facilitator. The results from this experiment serve to further understand the ability of groups to implicitly coordinate their work in an effort to categorize brainstorming ideas without a facilitator to guide the process and coordinate discussion and issue resolution. These results are central to the PD-GSS framework, allowing distributed groups to work autonomously during the collaborative process. Subsequent research activities are underway to examine additional contextual factors and constraints on the categorization process. The results from these experiments will guide the development of a prototype PD-GSS categorization module to be examined experimentally and in the field.

### 4.5.1. Subjects

Subjects for the second experiment were recruited from the Using and Managing Information Systems class within the Management Information Systems department in the Eller College of Management at the University of Arizona. The course is required of all majors within the College of Management and consists of primarily juniors and seniors. The subjects were given extra credit for their participation in the laboratory experiment. Two hundred seventy-eight subjects participated in this experiment; forty-four percent of the subjects were female with the average age of the subjects being 21.26 years.

### 4.5.2. Treatments and independent variables

The subjects worked together in groups of 3-4 individuals to categorize brainstorming solutions that would fix the school of business. The average size of the group was 3.4 subjects. The size of the groups was selected for two reasons. First, it represents a logical starting location for this initial, exploratory research. The experiment examines the implicit coordination abilities of the groups. As the size of the group increases, so does the complexity associated with the coordination. The smaller groups represent a valid place to examine the abilities of the groups to categorize before examining the abilities of increasingly large groups. Second, the group size approximates a possible range of users that may be actively working on a distributed, asynchronous project at any given time. This will be discussed further in the discussion of the treatments section.

A 2 x 3 experimental design, described below, was utilized during this experiment. Subjects were randomly assigned to one of the treatment groups. All treatments were tasked with utilizing GSS tools to categorize a set of brainstorming ideas into appropriate buckets. The brainstorming ideas provided to the groups were randomly selected from a pool of brainstorming ideas gathered during a previous brainstorming experiment (Santanen, 2002). In this manner, each of the groups started the categorization process with identical sets of brainstorming ideas to categorize. Group membership was strictly anonymous; group members did not know who was participating on their team. Additionally, no verbal communication was allowed. Only the GSS was used as a means to conduct the group work.

**Synchronicity**

The first independent variable examined during this experimental research was the synchronicity of the group interaction. Two treatments were used to examine this impact, synchronous and asynchronous group interaction. The synchronous groups could categorize the ideas freely as a team at the same time.

The other treatment mimicked an asynchronous environment. To achieve this effect in the laboratory setting, the groups utilized a turn taking mechanism to alternate turns while working as a group. When the participants were not working on the collaborative task, they could not view the brainstorming ideas, the categories, or any of the actions of their peers. This mock-asynchronous setting required the participants to work on the collaborative task in three to five minute segments. The laboratory assistant was responsible for timing the participants, starting new participants, and stopping participants when the time was up. The participants were free to end their turn prior to the five minute limit.

These two treatments represent, to an extent, the basic spectrum of a small group working asynchronously to collaborate. In this setting, at any given time there may be only one person working collaboratively or there may be a few individuals working collaboratively. The results provide information relevant to this spectrum of participants, including the related issues, results, and impacts on the satisfaction of group members.

**Quantity of brainstorming ideas**

The second dimension of the experimental design investigated the impact of the quantity of brainstorming ideas to be categorized. Groups were randomly assigned to one of three treatments, small, medium, or large quantities of ideas to be organized. No prior research existed to guide the selection of the specific quantities of brainstorming ideas. Discussion with experienced GSS facilitators provided guidance in setting the quantities. The small condition consisted of 30 brainstorming ideas, the medium condition consisted of 70 brainstorming ideas, and the large 110. Selection of the brainstorming ideas for each treatment proceeded as follows. First, 110 ideas were randomly selected from the pool of previously generated brainstorming ideas. Second, 70 brainstorming ideas were randomly selected from the pool of 110 brainstorming ideas. Lastly, 30 brainstorming ideas were randomly selected from the pool of 70 brainstorming ideas. The initial selection of 110 ideas sampled a set of raw brainstorming ideas that had not had any cleaning performed on them. No duplicates, non-solutions, or off-topics had been removed from the population in an effort to increase the generalizability of the results. Table 1 lists the number of groups that participated in each of the six treatment cells.

| | **Small** | **Medium** | **Large** |
|---|---|---|---|
| **Synchronous** | 13 | 14 | 14 |
| **Asynchronous** | 14 | 13 | 13 |

Table 1: Number of groups per treatment cell

### 4.5.3. Research questions

The objective of this research experiment was to further examine and understand the impacts of groups working without a facilitator to coordinate and guide the categorization of brainstorming ideas. Due to the lack of prior art in this area, formal hypotheses were not utilized. Instead, a series of overarching research questions were examined. These questions included the following:

1. What is the difference in the duration of time required to categorize the ideas?
2. What is the impact on the participants' satisfaction ratings with the process and the outcome?
3. What is the impact of synchronicity and brainstorming idea quantity on the quality of the clusters?
4. What characteristics are exhibited by the successful groups?

The impact of synchronicity may impact the group in different ways. It is plausible that synchronous groups may experience certain amounts of groupthink regarding the categories. The impact of groupthink may limit the amount of critical analysis and category revisions. The end result may be a set of categories that are not clustered as well as an asynchronous group. Asynchronous groups may exhibit less group think due to the lack of group interaction. The end result may be a set of categories that are of higher quality.

Alternatively, the asynchronous nature of the interaction may provide too much of a hindrance to the participants, limiting their overall effectiveness and efficiency such that the end result is not as high of quality as the synchronous treatments. Since the participants are working asynchronously, it is more difficult for them to process the changes and work performed by the other participants. This diminished ability to interact with the group may hinder the overall performance of the group.

The ability to observe and interact with the group in the synchronous treatments may increase the satisfaction ratings. Participants may feel more part of a group, increasing motivation to participate in the exercise (Homans, 1958; Tiwana & Bush, 2000). Alternatively, the synchronous nature of the exercise may frustrate the participants. The synchronous environment allows each participant to create buckets or move ideas at the same time. The result is a workspace that is constantly in flux. Participants may attempt to categorize the same brainstorming idea at the same time. However, only one person can categorize the idea. Similarly, the ability to read the brainstorming ideas is hampered. As ideas are categorized, the workstation screens refresh, moving the position of each brainstorming idea on the screen and hindering the ability of the participants to continue reading the brainstorming ideas. The end result of this dynamic workspace may reduce the overall satisfaction ratings as compared with asynchronous groups.

**4.5.4. Procedure**

Subjects were randomly assigned to one of the treatment cells upon arrival at the experimental laboratory, as described in the treatments section above. They were given their unique login information, which determined group membership. The subjects were placed into groups of 3-4 subjects and could sit randomly at one of the computer workstations within the GSS room. None of the participants knew which participants comprised which group. The group interaction during the experiment was conducted in an anonymous manner through the GSS.

The laboratory facilitator read from experiment's script to ensure consistent delivery of the instructions and experiment setup, see Appendix E. At the start of the experiment, the subjects were asked to read and accept the consent form and then asked to read the school of business task. After reading the task, each subject completed the demographic questionnaire. The subjects were then provided a demonstration of the GSS categorization tool and questions regarding the case study and the tool were clarified and resolved.

The participants were then allowed to categorize the brainstorming ideas into appropriate buckets based on their respective treatments. An existing GSS tool, ThinkTank by GroupSystems, was used by the groups to organize the brainstorming ideas into appropriate groups or buckets. All of the groups were provided with only a list of brainstorming ideas. No existing buckets were provided to the groups. Each group was tasked with creating and appropriately named buckets, moving the right brainstorming ideas into the buckets, and reviewing the buckets to verify that they were appropriate and that their names were appropriate. Each participant could add, edit, and delete buckets in addition to moving brainstorming ideas freely among the established buckets. As mentioned previously, this task examined the ability of each group to coordinate implicitly during the categorization process. No channels of communication were available to the participants to explain their actions, coordinate work, or perform any explicit decision making. This lack of a back-channel to communicate certainly reduces the efficiency and possibly the effectiveness of the group as the only way for members of the group to communicate was to observe the work of the other participants. Specifically, the participants could only see the buckets that the other group members had created and the brainstorming ideas that had been moved into the bucket. This experimental design mimics the context of a distributed, asynchronous environment where group members may not have the communication channels available to discuss or coordinate the collaborative work. Additional research needs to address the impact of differing communication means on a distributed, asynchronous categorization task.

The subjects were instructed to participate in the convergence task until they were satisfied with the results as a group; no time limits were imposed on the groups as the amount of time to complete the task was one of the variables of interest. More discussion of this and other measures are presented in the Dependent variables section that follows.

When the participants were satisfied with the categorization completed by their group, they were asked to create a flowchart explaining their thought process and overall course of action for completing this task. The flowchart was captured to gain further insight into the logic and thought process of the participants during the convergence process. These flowcharts were examined to further investigate the processes used by the successful and the unsuccessful groups to determine critical success factors. More details about the flowcharts the associated are presented later. After completing the flowcharts, the participants were each asked to complete a modified version of the same questionnaire used in experiment 1 regarding his or her experiences, see Appendix F. After completion of the questionnaire, the subjects were thanked and dismissed from the GSS room.

**4.5.5. Dependent variables and data collection**

The current research project's initial examination of groups' abilities to implicitly coordinate the categorization work analyzed various levels of the process and outcome. The measures and analysis of the results from the categorization task fall into three categories: analysis of the clusters of the actual brainstorming ideas, examination of the quantity of buckets and the number of changes to the buckets over the length of the experiment, satisfaction ratings with the process and outcome, and the process used by participants to categorize the brainstorming ideas.

Analysis of the brainstorming idea clusters investigated the accuracy of the clusters. The analysis consisted of comparing the clustering results from the groups to a clustering that was generated by a certified ThinkTank facilitator to determine the level of similarity. The similarity of the clusters was analyzed in terms of the number of missing or incorrect associations between brainstorming ideas. A metric called normalized clustering error was calculated for each of the clusters. This metric was utilized in previous research analyzing the accuracy of automated clustering approaches (D. Roussinov & Zhao, 2003; D. G. Roussinov & Chen, 1999). The metric analyzes the associations between the brainstorming ideas to determine how similar the group clusters are to the facilitator's cluster. Ideas that appear in the group's cluster but not the facilitator's cluster have incorrect associations between them. Ideas that appear in the facilitator's cluster but not in the group's cluster have missing associations. Normalized clustering error is defined as follows:

$$NCE = \frac{E}{A_t}$$

$E$ represents the total number of incorrect ($E_i$) and missing ($E_m$) associations in each group's clusters as compared with the facilitator's clusters:

$$E = E_i + E_m$$

The denominator, $A_t$, represents the total number of associations found in both the group's cluster and the facilitator's cluster. It represents the upper bound as the summation of all associations in the group and facilitator clusters. $A_t$ is calculated as follows:

$$A_t = A_g + A_f$$

$A_g$ represents the total number of associations between the brainstorming ideas in the group's clusters. $A_f$ represents the total number of associations between the brainstorming ideas in the facilitator's clusters. This metric possesses a range of zero to one. Zero means that there are no missing or incorrect associations between the group's clusters and the facilitator's clusters; the group categorized the brainstorming ideas in the same manner as the facilitator. One means that the group did not have any correct associations as compared with the facilitator.

An example of this metric is illustrated in Figure 13. This example and figure are taken from work by Roussinov and Zhao (2003).

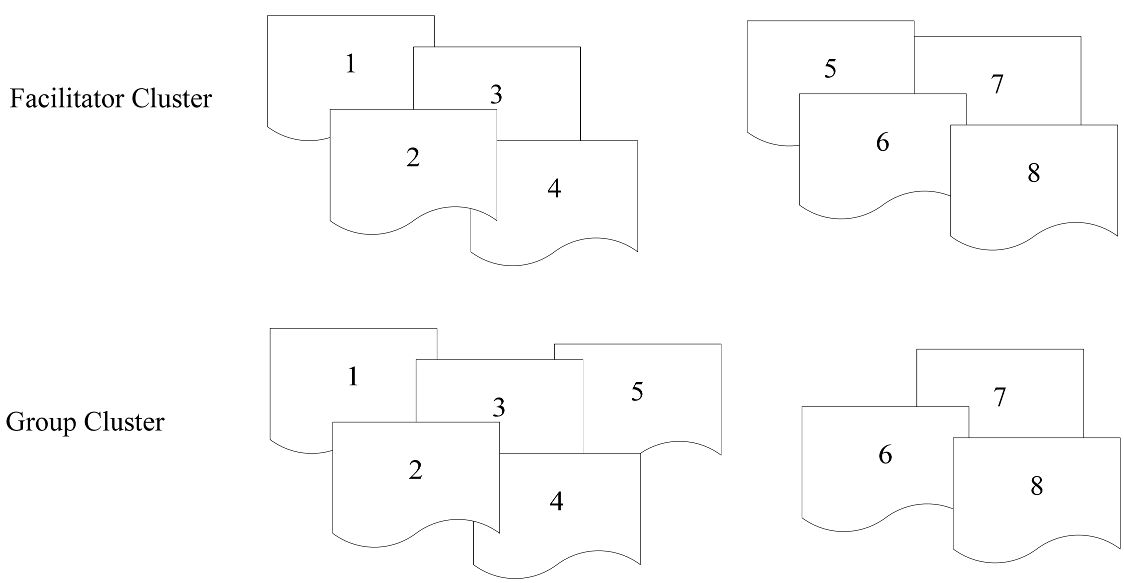


Figure 13: Normalized clustering error example from Roussinov and Zhao (2003)

In this example, the top row represents two clusters generated by the facilitator. The bottom row presents the clusters generated by the group. Comparing the two, the group made one error by placing brainstorming idea number 5 in the first cluster instead of the second cluster. This error results in four incorrect ($E_i$) associations (5-1, 5-2, 5-3, 5-4) and three missing ($E_m$) associations (5-6, 5-7, 5-8). Summing the incorrect and missing associations yields a total ($E$) of 7.

The total number of associations in the facilitator's cluster is 6 + 6 = 12. The total number of associations in the group's cluster is 10 + 3 = 13. The number of associations in a given cluster is calculated as $\frac{n(n-1)}{2}$, where $n$ equals the number of brainstorming ideas in a given cluster. The summation ($A_t$) in this example is 12 + 13 = 25. The normalized clustering error ($E / A_t$) is then calculated as 7 / 25 = 0.28.

Examination of the quantity of buckets and the number of changes to the buckets over the length of the experiment utilized several different measures. First, a new metric, the bucket change metric, was calculated to analyze the number of changes to the buckets over the life of the categorization task. During the experiment, snapshots were taken of each group's progress at set intervals. For the synchronous groups, snapshots were taken at five-minute intervals and 15 minute intervals for the asynchronous groups. These snapshots provided a listing of the buckets developed by the group and the brainstorming ideas within each bucket. The bucket change metric examined the number of changes to the buckets over the experimental task. The current research posits that the more changes to the buckets a group creates, the more refined and potentially better the outcome. Fewer changes indicate fewer refinements and a potentially lower quality output. This metric is calculated by analyzing the buckets at each snapshot and determining how many of the buckets remain unchanged in the following snapshot.

For example, in the first snapshot, there are 8 buckets that have been created by the group. In the second snapshot, we see that 7 of these buckets have not been changed. The bucket change metric for this interval is then 7 / 8 = 0.875. The change metric is calculated for each interval and averaged to yield an overall bucket change metric for each group over the entire categorization task. The bucket change metric is also zero to one bound. Zero indicates that every bucket is changed at every snapshot. One indicates that none of the buckets are changed between any of the snapshots.

Finally, the elapsed time and the number of buckets utilized in the final categorization submitted by the group were tabulated and analyzed. Self-report measures of satisfaction ratings with the process and outcome were gathered as part of the post-survey to better understand the impacts of the treatments on the participants' view of the process and results.

# CHAPTER 5 – RESEARCH ANALYSIS AND RESULTS

The previous chapter detailed the two experiments used to analyze and further the PD-GSS framework. This chapter presents the statistical methods used to examine the research questions derived from the model based upon the data gathered during the experiments described in Chapter 4.

## 5.1. Experiment 1 – divergence – results

This section outlines the statistical analysis and results from the brainstorming experiment. The control treatment included groups that brainstormed in a traditional, uncontrolled brainstorming session. The treatment groups utilized the controlled, peer-reviewed brainstorming process to brainstorm solutions as a group. This section addresses each of the research questions outlined in Chapter 4.

**Does the peer-review process limit the quantity of noise?**

The total number of invalid ideas for each group was calculated as the summation of the off-topic, non-solution, and duplicate comments. An independent samples t-test was performed to investigate the differences between the control and treatment groups. The results indicate that the treatment exhibited a near significant difference in the quantity of noise as compared with the control $t(7) = 1.766$, $p = .075$ (one-tailed). The control group had a mean number of invalid ideas of 20.40 ($SD = 20.56$) while the treatment group had a mean number of 4.00 ($SD = 2.58$). The descriptive statistics for the invalid ideas by condition are presented Table 2.

| Condition | | Mean | Std. Deviation |
|---|---|---|---|
| Control | Off-Topic | 0 | |
| | Non-Solutions | 20.00 | 22.061 |
| | Duplicates | 4.40 | 2.408 |
| Treatment | Off-Topic | 0 | |
| | Non-Solutions | 1.50 | .707 |
| | Duplicates | 3.25 | 2.872 |

Table 2: Invalid comments by treatment

**Does the peer-review process limit the quality of ideas generated?**

The first analysis compared the mean quality of the valid ideas generated for each treatment. Independent samples t-tests were performed to compare the control and treatment conditions for both the creativity and feasibility dimensions. The mean values for these conditions are presented in Table 3.

| | Condition | Mean | Std. Deviation |
|---|---|---|---|
| Creativity | Control | 3.5720 | .15595 |
| | Treatment | 3.7720 | .23784 |
| Feasibility | Control | 3.6800 | .07211 |
| | Treatment | 3.7800 | .07036 |

Table 3: Mean quality ratings by condition

The treatment condition produced a near significant difference in the average creativity rating, $t(8) = .077$ (one-tailed). The treatment condition did produce significant results for the average feasibility rating, $t(8) = 2.219$, $p < .05$ (one-tailed).

**What is the impact on the number of valid ideas generated?**

The raw total numbers of ideas generated as well as the number of valid ideas generated for each treatment are presented in Table 4.

| Condition | | Mean | Std. Deviation |
|---|---|---|---|
| Control | Total Comments | 34.00 | 12.356 |
| | Valid Comments | 21.00 | 2.449 |
| Treatment | Total Comments | 16.20 | 3.347 |
| | Valid Comments | 13.00 | 2.828 |

Table 4: Mean of total comments and valid comments by condition

The percentage of valid ideas generated in the control condition was 61%. The percentage of valid ideas for the treatment condition was 82%. The control condition generated significantly more ideas overall than the treatment condition, $t(7) = 3.131$ , $p < .05$. Likewise, the number of valid ideas in the control condition was significantly higher than in the treatment condition, $t(7) = 4.462$ , $p < .01$.

**What are the impacts on the number of high-quality ideas?**

Previous research in electronic brainstorming has indicated that one effective way of analyzing the quality of brainstorming is to assess the count of "good" ideas (Dennis et al., 1997; B. A. Reinig & Briggs, 2006). In the current research, ideas that were rated 3.50 or above on the creativity or feasibility scales were considered "good". Ideas that were below 3.00 were classified as low quality for both quality dimensions.

Independent samples t-tests were performed to compare the quantity of good ideas and low quality ideas between the control and treatment conditions. Table 5 presents the descriptive statistics for the high creative and high feasibility ideas.

| | Condition | Mean | Std. Deviation |
|---|---|---|---|
| High Creative | Control | 13.40 | 4.159 |
| | Treatment | 10.40 | 3.435 |
| High Feasible | Control | 15.20 | 1.924 |
| | Treatment | 10.00 | 3.162 |

Table 5: Quantities of high creativity and high feasiblity ideas by treatment

No significant difference was found between the control and treatment conditions regarding the quantity of highly creative ideas, $t(8) = 1.244$, $p = .249$. Comparison between the high feasibility ideas yielded a significant difference. The control group produced a significantly higher quantity of highly feasible ideas, $t(8) = 3.141$, $p < .05$.

Similar analysis was performed to investigate the difference in quantities of the low creativity and low feasibility ideas. Table 6 presents the summary statistics.

| | Condition | Mean | Std. Deviation |
|---|---|---|---|
| Low Creative | Control | 2.60 | 1.517 |
| | Treatment | .40 | .894 |
| Low Feasible | Control | 2.00 | .707 |
| | Treatment | .40 | .548 |

Table 6: Quantities of low creativity and low feasibility ideas by treatment

The control condition produced significantly more low creativity, $t(8) = 2.794$, $p < .05$, and low feasibility, $t(8) = 4.0$, $p < .05$, ideas than the treatment condition.

**What are the impacts on participants' satisfaction with the process and the results?**

Summary statistics for the process satisfaction and outcome satisfaction measures obtained during the post-survey are presented in Table 7.

| | Condition | N | Mean | Std. Deviation |
|---|---|---|---|---|
| Process Satisfaction | Control | 32 | 3.7031 | .97434 |
| | Treatment | 35 | 4.2714 | .74105 |
| Outcome Satisfaction | Control | 32 | 3.8281 | .73627 |
| | Treatment | 35 | 4.1000 | .81168 |

Table 7: Process and outcome satisfaction ratings by treatment

The treatment condition produced significantly higher process satisfaction ratings than the control condition, $t(65) = -2.701$, $p < .05$. The treatment condition produced a near-significant result for outcome satisfaction as well, $t(65) = -1.431$ , $p = .075$ (one-tailed).

**Miscellaneous results**

Independent samples t-tests were conducted to compare how effective the subjects felt their respective groups were at generating brainstorming ideas. The treatment condition, 4.09 ($SD = .880$), received slightly higher ratings than the control condition, 3.75 ($SD = .919$). However, there was no significant difference between the effectiveness ratings between the control and treatment conditions, $t(65) = -1.524$ , $p = .132$.

Analysis was also conducted to examine the ratings of how much each subject felt she participated in the group brainstorming exercise. Subjects in the treatment condition, 4.26 ($SD = .641$), rated their participation higher than subjects in the control condition, 3.91 ($SD = .852$). The treatment condition received significantly higher participation ratings than the control condition, $t(65) = -1.891$ , $p < .05$ (one-tailed).

Lastly, the brainstorming version that was selected as the "best" was analyzed for the brainstorming ideas in the treatment condition. The original version of the brainstorming idea was selected as the best 30.86% of the time. Versions two and three were selected 23.46% and 45.68% of the time, respectively. It should be noted that versions two and three occur in parallel and independently. Version three does not benefit from being able to see version one and two. This distribution indicates that the peers who authored the second and third versions of the original comment could improve upon the original idea in order for it to be selected as the "best" version part of the time.

## 5.2. Experiment 2 – convergence – results

This section outlines the statistical analysis and results from the categorization experiment. The treatments included groups that organized the brainstorming ideas in synchronous and asynchronous contexts. The groups were responsible for categorizing either a small (30 ideas), medium (70 ideas), or large (110 ideas) set of brainstorming ideas. This section addresses each of the research questions outlined in Chapter 4.

**What is the difference in duration of time required to categorize the ideas?**

The first set of analyses investigated the time duration required by each group to complete the categorization task. The elapsed time was calculated for each group. This elapsed time was then divided by the number participants in the group to arrive at the average time spent per person on the task. This average time was then analyzed using a 2 (synchronicity) x 3 (brainstorming idea quantity) factorial MANOVA to investigate the difference in the amount of time expended between the treatments. The means and standard deviations associated with the average time are presented in Table 8.

| Timing | Quantity | | Mean | Std. Deviation |
|---|---|---|---|---|
| Asynchronous | Large | Average Time | 20.0697 | 4.97347 |
| | Medium | Average Time | 14.5059 | 3.66520 |
| | Small | Average Time | 11.5771 | 1.55406 |
| Synchronous | Large | Average Time | 37.3148 | 6.28417 |
| | Medium | Average Time | 22.4705 | 3.11388 |
| | Small | Average Time | 14.2648 | 2.55434 |

Table 8: Means of the average time per person by treatment cell

The results of the MANOVA identify significant main effects for the synchronicity, $F(1, 75) = 102.95$, $p < .01$, partial $\eta^2 = .59$, and the quantity of brainstorming ideas, $F(2, 74) = 99.99$, $p < .01$, partial $\eta^2 = .74$. The synchronicity and the quantity of brainstorming ideas required significantly different time to complete the categorization process. Additionally, there was a significant interaction effect between synchronicity and quantity, $F(2, 74) = 21.21$, $p < .01$, partial $\eta^2 = .37$. Figure 14 represents the mean average times for the treatments. The quantity of ideas increases from left to right: small, medium, and large quantities. The top line represents the synchronous group while the bottom line represents the asynchronous groups.

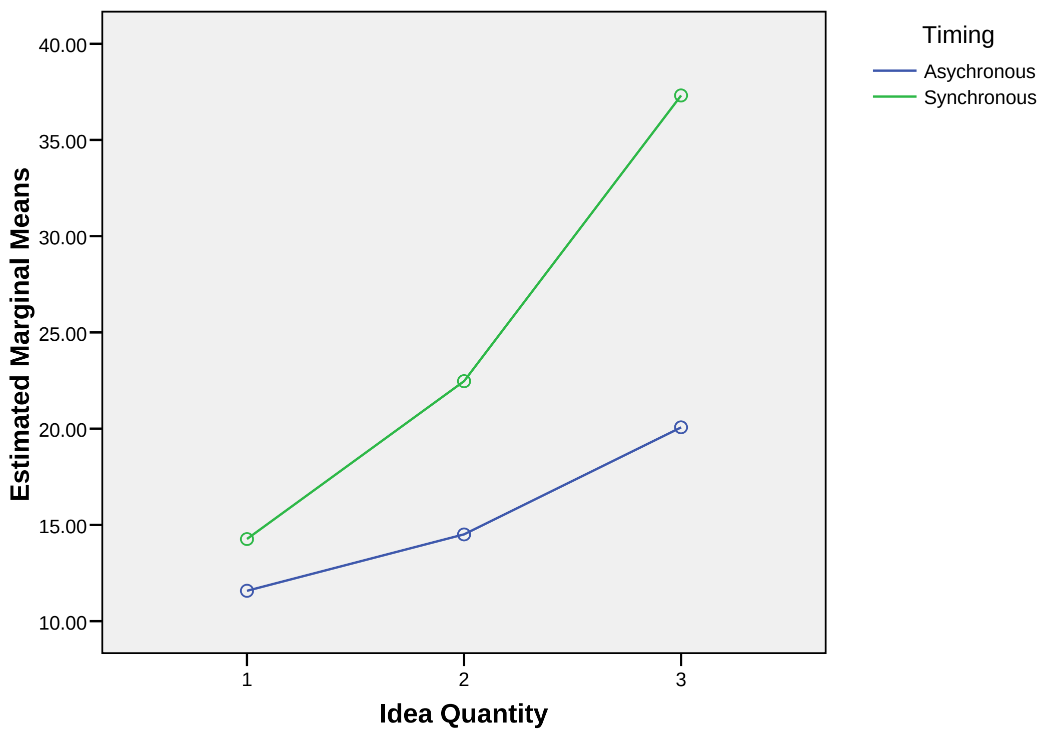


Figure 14: Average time per person by treatment

The asynchronous groups completed the required categorization in significantly less time per person than the synchronous groups. The average time expended per person also increased significantly as the quantity of ideas to organize increased.

Helmert contrasts were performed to partition the degrees of freedom and further investigate the differences between the quantities of brainstorming ideas for each synchronicity treatment. The first contrast compared small (-2) to medium (+1) and large (+1). The second contrast compared medium (-1) to large (+1). In the asynchronous treatment, there was a significant difference between the small and the other two quantities ($p < .01$). Additionally, the medium treatment was significantly less than the large treatment ($p < .01$). The same contrasts were performed on the synchronous treatment. The same results were obtained. The small treatment was significantly less than the medium and large treatments ($p < .01$). The medium and large treatments were significantly different ($p < .01$).

The lines plotted in Figure 14 indicate that there is potentially a non-linear relationship between the average time and the quantity of brainstorming ideas. To investigate this relationship further, a curve fitting procedure was performed to examine if the relationship fit a linear model or an exponential model better. In the asynchronous treatment, the linear model produced an $R^2$ of .49 while the exponential model produced an $R^2$ of .51. In the synchronous treatment, the linear model produced an $R^2$ of .81 while the exponential model produced an $R^2$ of .86. These results support the idea that the relationship is exponential. As the quantity of brainstorming ideas grows linearly, the average time required per person to categorize the ideas increases exponentially.

**What is the impact on the participants' satisfaction ratings with the process and the outcome?**

The first analysis examined the treatments' impact on the participants' satisfaction with the categories produced in the end by their respective group. Table 9 presents the mean and standard deviation statistics regarding this outcome satisfaction measure.

| Synchronicity | | N | Mean | Std. Deviation |
|---|---|---|---|---|
| Synchronous | Categories Satisfaction | 132 | 3.89 | .807 |
| Asynchronous | Categories Satisfaction | 142 | 3.87 | .780 |

Table 9: Mean outcome satisfaction ratings by synchronicity

A 2 (synchronicity) x 3 (brainstorming idea quantity) factorial MANOVA was performed to compare the levels of outcome satisfaction. No significant differences were found between the synchronicity treatments ($p$ = .87) or the brainstorming quantity treatments ($p$ = .88). The treatments exhibited no significant effect on the satisfaction of the participants with the output generated by their respective teams.

The next analysis examined the participants' satisfaction with the categorization process. Another MANOVA was performed to examine the differences between the treatments. The descriptive statistics for the process satisfaction metric are found in Table 10.

| Synchronicity | Quantity | | N | Mean | Std. Dev |
|---|---|---|---|---|---|
| Synchronous | Small | Process Satisfaction | 42 | 3.9524 | .91605 |
| | Medium | Process Satisfaction | 47 | 3.8617 | .72007 |
| | Large | Process Satisfaction | 43 | 3.8953 | .79101 |
| Asynchronous | Small | Process Satisfaction | 50 | 3.4900 | .85410 |
| | Medium | Process Satisfaction | 44 | 3.8864 | .73027 |
| | Large | Process Satisfaction | 48 | 3.5521 | .83309 |

Table 10: Process satisfaction means by treatment

The results of the MANOVA indicated there was no significant difference between the quantity of ideas to be categorized ($p$ = .347). A significant difference existed between the synchronous and asynchronous process satisfaction ratings, $F(1, 271) = 7.05$, $p < .01$, partial $\eta^2 = .03$. Further analysis of each synchronicity treatment indicated that no significant difference existed between the quantity of brainstorming ideas for the synchronous treatment.

The asynchronous treatment, however, produced a significant effect between the quantity of brainstorming ideas, $F(2, 138) = 3.17$, $p < .05$, partial $\eta^2 = .04$. Three custom contrasts were created to compare the three levels of brainstorming idea quantities for the asynchronous treatment. The first contrast compared the small (+1) and large (+1) treatments to the medium (-2) treatment. The second contrast compared the medium (-1) and large (+1) treatments. The last contrast compared the small (+1) treatment to the medium (-1) treatment. All three contrasts were significant, indicating that all three brainstorming quantity treatments yielded significantly different process satisfaction ratings, see Table 11. The medium size brainstorming quantity yielded significantly higher process satisfaction ratings from the participants in the post-survey in the asynchronous treatment.

| | Contrast | Value of Contrast | Std. Error | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|
| Process Satisfaction | 1 | -.7306 | .29416 | -2.484 | 139 | .014 |
| | 2 | -.3343 | .16915 | -1.976 | 139 | .050 |
| | 3 | -.3964 | .16752 | -2.366 | 139 | .019 |

Table 11: Custom contrasts comparing process satisfaction for each bucket quantity in the asynchronous treatment

The next set of analyses examined additional measures that were gathered via the post-survey, experience enjoyment, amount of individual participation, and motivation to categorize well. These measures are an important factor in user involvement and the level of motivation to fully participate in the collaborative efforts. Significant correlations exist between these three measures, see Table 12.

| | | Individual Participation | Motivation |
|---|---|---|---|
| Enjoyable | Pearson Correlation | .215(**) | .278(**) |
| | Sig. (2-tailed) | .000 | .000 |
| | N | 274 | 274 |

** Correlation is significant at the 0.01 level (2-tailed).

Table 12: Correlation between enjoyment, individual participation and motivation

The first item examined was the participants' ratings of how enjoyable they found the experience. Descriptive statistics of the enjoyable metric are found in Table 13.

| Synchronicity | Brainstorming Quantity | N | Mean | Std. Deviation |
|---|---|---|---|---|
| Synchronous | Small | 42 | 3.57 | .831 |
| | Medium | 47 | 3.13 | .850 |
| | Large | 43 | 3.77 | .782 |
| Asynchronous | Small | 50 | 2.96 | .989 |
| | Medium | 44 | 3.20 | 1.025 |
| | Large | 48 | 2.94 | .909 |

Table 13: Mean and standard deviation statistics for participant enjoyment by treatment

A 2x3 factorial MANOVA was performed to compare the participant enjoyment ratings by treatment. Quantity of brainstorming ideas did not produce a significant main effect ($p = .38$). Synchronicity produced a significant main effect, $F(1, 271) = 17.27$, $p < .01$, partial $\eta^2 = .06$. Subjects enjoyed the synchronous treatment significantly more than those in the asynchronous treatment. A significant interaction effect existed between synchronicity and quantity, $F(2, 270) = 6.22$, $p < .01$, partial $\eta^2 = .04$.

One-way ANOVAs were performed for each of the synchronicity treatments to further examine the difference between quantities of brainstorming ideas. No significant difference was found in the asynchronous treatment. In the synchronous treatment, the difference in enjoyment ratings between idea quantity was significant, $F(2, 270) = 7.20$, $p < .01$, partial $\eta^2 = .1$. Three custom contrasts were performed to examine each level of brainstorming ideas quantity against each other. The same contrasts described earlier were used. The first contrast compared the small (+1) and large (+1) treatments to the medium (-2) treatment. The second contrast compared the medium (-1) and large (+1) treatments. The last contrast compared the small (+1) treatment to the medium (-1) treatment. All three contrasts were significant, indicating that all three brainstorming quantity treatments yielded significantly different enjoyment ratings, see Table 14. The small and large size brainstorming quantities yielded significantly higher enjoyment ratings from the participants in the post-survey in the synchronous treatment.

| | Contrast | Value of Contrast | Std. Error | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|
| Enjoyable | 1 | 1.08 | .299 | 3.625 | 129 | .000 |
| | 2 | .64 | .173 | 3.688 | 129 | .000 |
| | 3 | .44 | .175 | 2.542 | 129 | .012 |

Table 14: Custom contrasts comparing process enjoyment for each bucket quantity in the synchronous treatment

The next analysis examined the participants' rating of perceived level of individual participation. The means and standard deviations for the individual participation ratings are presented in Table 15.

| Synchronicity | Brainstorm Quantity | N | Mean | Std. Deviation |
|---|---|---|---|---|
| Synchronous | Small | 42 | 4.02 | .950 |
| | Medium | 47 | 4.21 | .931 |
| | Large | 43 | 4.47 | .592 |
| Asynchronous | Small | 50 | 3.86 | .969 |
| | Medium | 44 | 3.95 | .888 |
| | Large | 48 | 4.08 | .767 |

Table 15: Mean and standard deviation statistics for individual participation by treatment

A 2x3 factorial MANOVA was performed to compare individual participation ratings by treatment. Quantity of brainstorming ideas, $F(2, 270) = 3.41$, $p < .05$, partial $\eta^2 = .03$ , and synchronicity, $F(1, 271) = 6.59$, $p < .05$, partial $\eta^2 = .03$, both produced significant main effects. Subjects felt they participated more in the synchronous treatment. Participants in the larger treatments also felt they participated more than those in the smaller treatment.

One-way ANOVAs were performed for each synchronicity treatment to investigate potential differences in the quantities of brainstorming ideas. In the asynchronous treatment, no significant difference was identified between brainstorming idea quantities in relation to individual participation ($p = .454$). In the synchronous treatment, a near significant main effect exists between brainstorming idea quantity and individual participation ($p = .56$). Helmert contrasts were performed to further examine the differences. The first contrast compared the small (-2) quantity to the medium (+1) and large (+1) quantities. The second contrast compared the medium (-1) quantity to the large quantity (+1). The first contrast was significant ($p < .05$) while the second was not ($p = .158$). The medium and large quantities were significantly higher than the small quantity for participants' rating their level of personal involvement.

Analysis of the participant's level of motivation to categorize the solutions well was also analyzed via a 2x3 factorial MANOVA. The means and standard deviations are presented in Table 16.

| Synchronicity | Brainstorm Quantity | N | Mean | Std. Deviation |
|---|---|---|---|---|
| Synchronous | Small | 42 | 3.7381 | 1.08334 |
| | Medium | 47 | 3.7021 | 1.01970 |
| | Large | 43 | 4.1860 | .76394 |
| Asynchronous | Small | 50 | 3.3200 | 1.13281 |
| | Medium | 44 | 3.5455 | 1.10925 |
| | Large | 48 | 3.7708 | .85650 |

Table 16: Motivation to catetorgize well means and standard deviations by treatment

Quantity of brainstorming ideas, $F(2, 270) = 5.05$, $p < .05$, partial $\eta^2 = .04$ , and synchronicity, $F(1, 271) = 7.36$, $p < .05$, partial $\eta^2 = .03$, both produced significant main effects. Subjects' motivation to categorize the solutions well was significantly higher in the synchronous treatment.

One-way ANOVAs were performed to investigate each synchronicity treatment separately. In the synchronous treatment, brainstorming idea quantity produced a significant difference, $F(2, 128) = 3.40$, $p < .05$, partial $\eta^2 = .05$. As with the previous analyses, Helmert contrasts were performed to compare the three brainstorming quantities. There was no significant difference between the small treatment and the medium and large treatments ($p = .256$). However, there was a significant difference between the medium treatment and the large treatment ($p < .05$). The large treatment generated significantly higher motivation to perform well on the task. No significant difference was observed in the asynchronous treatment ($p = .104$).

**What is the impact of synchronicity and brainstorming idea quantity on the quality of the clusters?**

The first analysis consisted of comparing the normalized clustering error for each of the treatment cells. The normalized clustering error represents how accurate each group's cluster was as compared with the expert facilitator's cluster. A zero means that there were no errors and that the group matched the facilitator's results perfectly. A one means that the group did not have any correct brainstorming ideas together in a cluster as compared with the facilitator. Means and standard deviations for the normalized clustering errors for each treatment are presented in Table 17.

| Synchronicity | Size | | N | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Asynchronous | Large | NCE | 13 | .813303 | .0469573 |
| | Medium | NCE | 12 | .847154 | .0442340 |
| | Small | NCE | 14 | .806652 | .0421714 |
| Synchronous | Large | NCE | 13 | .787851 | .0456545 |
| | Medium | NCE | 14 | .821448 | .0566204 |
| | Small | NCE | 13 | .782064 | .0664508 |

Table 17: Normalized clustering error means and standard deviations by treatment

Figure 15 presents a plot of the mean normalized clustering error by treatment. The top line represents the asynchronous treatment and the bottom line represents the synchronous treatment.

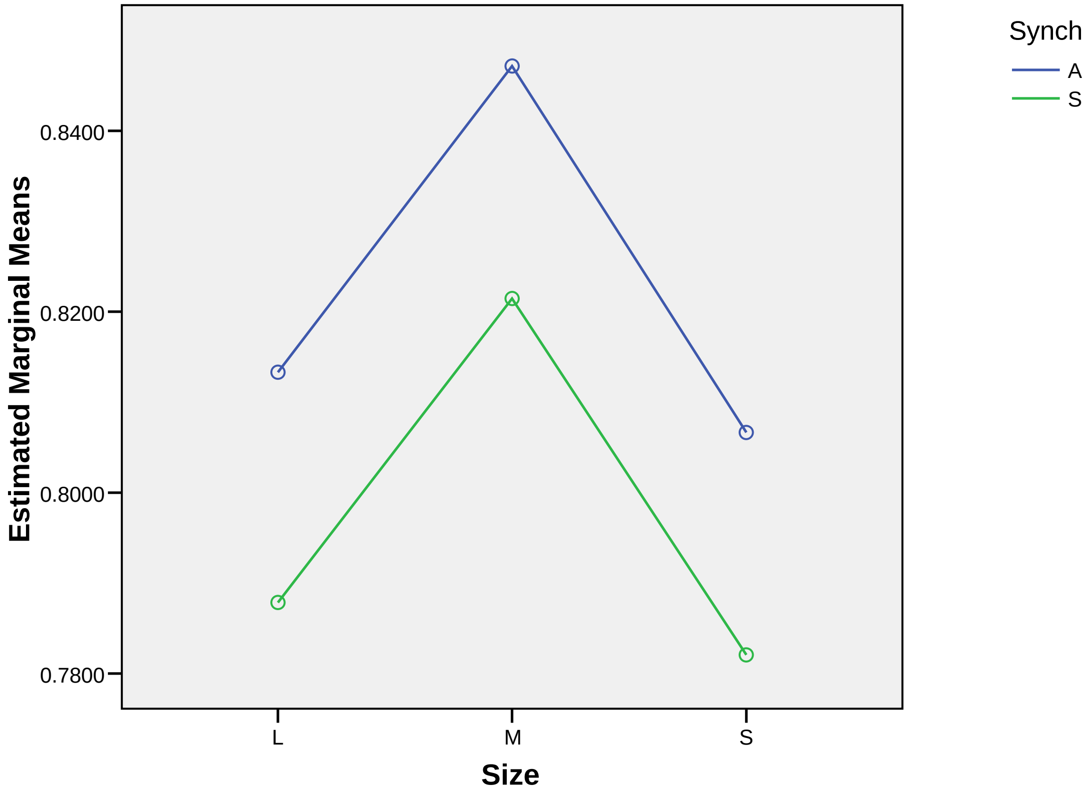


Figure 15: Mean normalized clsutering error by treatment

A 2x3 factorial MANOVA compared the normalized clustering errors for each of the treatments. Significant main effects were found for both synchronicity, $F(1, 76) = 4.81$, $p < .05$, partial $\eta^2 = .06$, and brainstorming idea quantity, $F(2, 75) = 4.62$, $p < .05$, partial $\eta^2 = .11$.

The data set was further analyzed by synchronicity treatment to investigate the differences between brainstorming idea quantity using custom contrasts. The first contrast compared the small (+1) and large (+1) treatments to the medium (-2) treatment. The second contrast compared the medium (-1) and large (+1) treatments. The third contrast compared the small (+1) treatment to the medium (-1) treatment. The last treatment compared the small (+1) treatment to the large (-1) treatment. In the asynchronous treatment, the medium treatment was significantly higher than the small and medium groups, $p < .05$. The medium treatment was also significantly than the large treatment, $t(36) = -1.90$, $p < .05$ (one-tailed), and small treatment, $t(36) = -2.32$, $p < .05$, separately. No significant difference was found between the small and large treatments.

In the synchronous treatment, the medium treatment was significantly higher than the small and large treatments, $t(37) = -1.94$, $p < .05$ (one-tailed). There was also a significant difference between the small and medium treatments, $t(37) = -1.80$, $p < .05$ (one-tailed). No significant difference was found between the small and large treatments.

Normalized clustering error examined the contents of each bucket to determine which ideas were collocated within the same buckets. The next analysis examined the names of the categories themselves to determine the frequency of changes to the bucket names using the bucket change metric. Again, this metric is zero to one scaled, with a zero indicating that every bucket was changed during every snapshot interval. A score of one indicates that none of the buckets were changed during the snapshot intervals. This research posits that more changes to the bucket names, a lower bucket change metric, is indicative of more critical analysis within the group and ultimately more refined buckets.

A 2x3 factorial MANOVA was performed to examine the differences in the bucket change metric between the treatments. Figure 16 presents the bucket change metric means for each of the treatments. The top line represents the synchronous treatment and the bottom line the asynchronous treatment. The brainstorming idea quantity is listed across the X axis (large, medium, and small) from left to right.

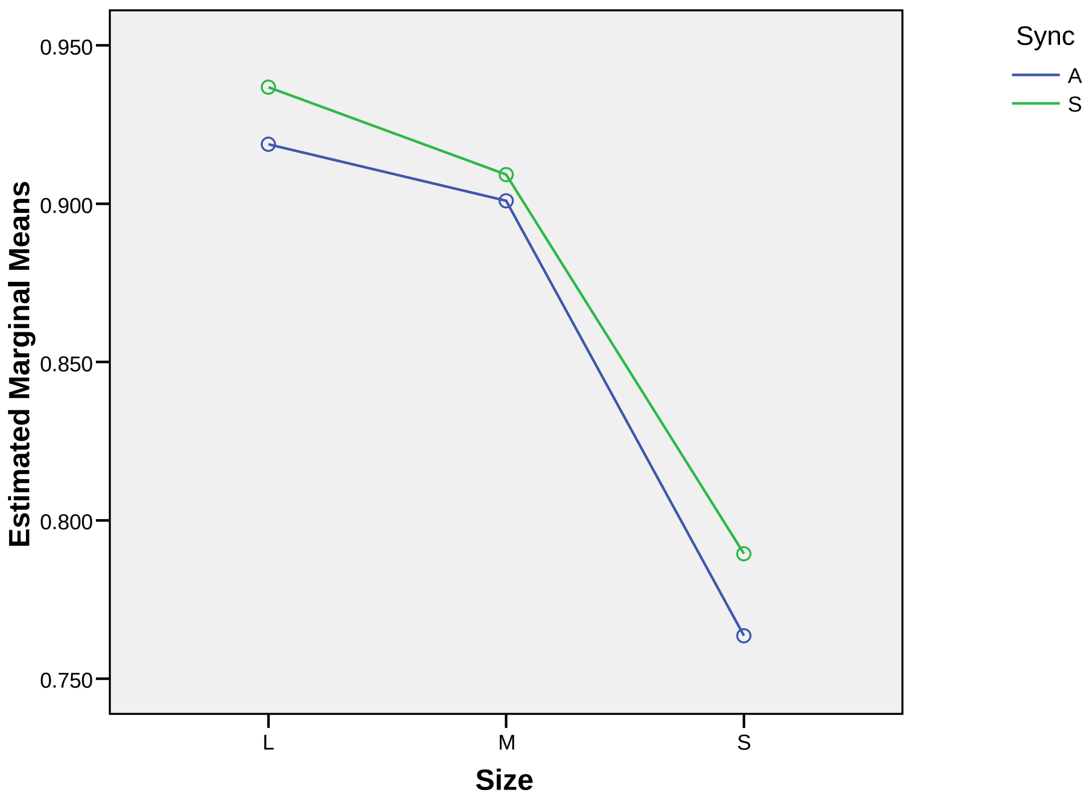


Figure 16: Bucket change matric means by treatment

A significant main effect was found for the brainstorming idea quantity, $F(2, 77) = 16.78$, $p < .05$, partial $\eta^2 = .31$. Helmert contrasts were performed on each synchronicity treatment to further examine the differences between treatments. In the asynchronous treatment, a significant difference existed between the small treatment and the medium and large treatments ($p < .01$). No difference existed between the medium and large treatments ($p = .67$). Similar results were exhibited in the synchronous treatment. The small treatment was significantly lower than the medium and large treatments, ($p < .01$). No difference existed between the medium and large treatments ($p = .48$).

The next section of analysis investigates the relationships between the bucket change metric, the final number of buckets generated by each group, and the elapsed time. First, bivariate correlations were performed between the final number of buckets and elapsed time and the bucket change metric. This correlation is presented in Table 18.

| | | Elapsed Time | Bucket Change Metric |
|---|---|---|---|
| Final Number of Buckets | Pearson Correlation | .468(*) | .554(*) |
| | Sig. (2-tailed) | .000 | .000 |
| | N | 81 | 81 |

* Correlation is significant at the 0.01 level (2-tailed).

Table 18: Correlation between the final number of buckets, elapsed time, and the bucket change metric

The correlations were all significant at the .01 level. As the final number of buckets generated by the group increases, so does the time required to generate those buckets. Additionally, as the number of buckets increases, the bucket change metric increases, indicating fewer edits and revisions to the existing buckets.

Linear regressions were performed to examine the predictive power of the final number of buckets on the elapsed time and the bucket change metric. The final number of buckets generated by each group was a significant predictor of the amount of time elapsed for the categorization task, $F(1, 76) = 22.11$, $p < .01$. The $R^2$ for this model was .22. The coefficients and significance levels are presented in Table 19.

| Model | | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | t | Sig. |
| 1 | (Constant) | 11.009 | 6.777 | | 1.624 | .108 |
| | Final N Buckets | 2.955 | .628 | .468 | 4.702 | .000 |

Table 19: Coefficients from linear regresssion predicting elapsed time from the final number of buckets

Likewise, the final number of buckets generated was a significant predictor of the bucket change metric, $F(1, 76) = 33.61$, $p < .01$. The $R^2$ for this model was .30. The coefficients and significance levels are presented in Table 20.

| Model | | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | t | Sig. |
| 1 | (Constant) | .638 | .042 | | 15.346 | .000 |
| | Final N Buckets | .022 | .004 | .551 | 5.797 | .000 |

Table 20: Coefficients from linear regression predicting bucket change metric from the final number of buckets

**What characteristics are exhibited by the successful groups?**

To investigate the workflows and properties of successful and unsuccessful groups, the flowcharts were stratified into differing groups. The term successful is defined as being either one of the top five groups in the normalized clustering error metric or the bucket change metric. Two separate groups were generated from the population according to these criteria. Alternatively, the bottom five groups in normalized clustering error and the bucket change metric were extracted and grouped into sub-groups for further examination. The flowcharts from these four different sub-groups were reviewed to determine differences between the successful and the unsuccessful groups. The goal of this review was to identify processes or specific workflows that may have influenced the group's outcome.

Analysis of the top and bottom performers for each metric, normalized clustering error and bucket change, identified two possible reasons for the differences between the top and bottom performing groups. First, groups that performed well often included specific steps to read all of the brainstorming ideas up front, at the beginning of the exercise, to gain context and to, in their words, "group the ideas mentally" before starting the actual categorization through the GSS tool. By reading the ideas first, the individuals were able to gain situation awareness and better understand the solution space provided by the brainstorming ideas. It appears that groups not reading enough brainstorming ideas initially were less able to understand the range of solutions and develop appropriate buckets for them.

The second difference between the successful and less successful groups examined was that the successful groups included specific steps to review, edit, and refine the bucket labels themselves as well as the categorization scheme. Some of the groups utilized reviews in the middle of the task to review buckets and reassign ideas while others performed a first draft categorization and then revised and updated this categorization toward the latter end of the task. The groups that performed poorly did not make use of comprehensive reviews, limiting the effectiveness of the group's performance. The possible explanations for these results are twofold. First, the groups may not have clearly understood the task, the objectives of the task, and the functionality of the tool. Instructions were provided to show the groups how to perform the editing process and the groups were urged to review and refine the work. However, confusion may have existed either with the tool or the overall objective of the experiment. Second, the task in and of itself may be too complex to be assigned as one task. The categorization task, as examined experimentally, consists of several sub-tasks. The groups must first read and understand the brainstorming ideas to gain further context and situation awareness regarding the issues and the potential buckets. The groups then create the buckets and assign the appropriate comments to each bucket. A reviewing process must then be conducted to refine the buckets, renaming the bucket, splitting large buckets into multiple buckets, or even consolidating similar buckets. It is plausible that the categorization task itself needs to be subdivided into discrete stages or sub-tasks in order to minimize the cognitive load and improve the understanding of the current task and the desired results from the current task.

To further examine the relationship between groups that read all the ideas at the beginning of the process and those that completed revision steps and their performance, the flowcharts from the top 15 groups and the bottom 15 groups for both the normalized clustering error and the bucket change metrics were examined. The average count of the number of individuals reading all the ideas first was tabulated and correlated with the two performance metrics to explore this relationship. Likewise, the count of the average number of review steps per person on the group was correlated with the two performance metrics. Any steps in the flowcharts that indicated a revision or editing step was counted. The total number of revision steps by the group was then divided by the number of individuals in the group to arrive at the average number of revision steps per group member. This measure was then correlated with the normalized clustering error and the bucket change metric. Table 21 and Table 22 present the correlations between the counts and the performance metrics.

| | | Read All Ideas | Review Steps |
|---|---|---|---|
| NCE | Pearson Correlation | -.389(*) | -.427(*) |
| | Sig. (2-tailed) | .034 | .018 |
| | N | 30 | 30 |

* Correlation is significant at the 0.05 level (2-tailed).

Table 21: Correlation between reading all ideas and review steps with the normalized clustering error performance metric

| | | Read All Ideas | Review Steps |
|---|---|---|---|
| Bucket Change Metric | Pearson Correlation | -.028 | -.405(*) |
| | Sig. (2-tailed) | .881 | .027 |
| | N | 30 | 30 |

* Correlation is significant at the 0.05 level (2-tailed).

Table 22: Correlation between reading all ideas and review steps with the bucket change metric

The correlations between normalized clustering error and the average count of individuals reading all the ideas at first and the number of review steps were negative and significant. As the normalized clustering error increased (i.e., the group performed more poorly), the number of individuals reading all the ideas up front decreased and the number of review steps performed by the group decreased. Looking at the bucket change metric, the correlation was negative and significant between the average count of review steps and the bucket change metric.  As the bucket change metric increases (i.e., the group performed more poorly), the number of review steps decreased.  A clear link existed between the review steps engaged by the team members and the performance metrics.

# CHAPTER 6 – DISCUSSION

This chapter contains a discussion of the experimental results that were presented in Chapter 5. The discussion parallels the structure of the previous chapter, presenting discussion of each experiment separately, and offers interpretations and insights to the PD-GSS based upon the evidence obtained from the problem solving tasks. The limitations associated with this research are presented.

## 6.1. Experiment 1 – divergence - discussion

This section discusses the major findings from the pilot study about peer-reviewed brainstorming. The goal of peer-reviewed brainstorming is to provide some control over the brainstorming process. Rather than allow any participant to submit any type of input, the review process forces each brainstorming idea to be reviewed and edited by a random peer. The ultimate goal of this review process is to reduce the quantity of noise in the brainstorming ideas and to improve the overall quality of the brainstorming ideas.

The statistical analysis presented in Chapter 5 indicates that the peer-review process did control the volume of brainstorming ideas generated by the group. The control groups, traditional GSS brainstorming, generated a significantly larger quantity of brainstorming ideas overall as compared with peer-reviewed system. Next the duplicates, off-topic, and non-solution comments were removed from the set of brainstorming ideas, leaving the valid ideas. Sixty-one percent of the overall ideas generated in the control condition were valid compared with 82% in the treatment condition. Looking at the specific numbers, the control condition produced statistically higher quantities of valid comments. Looking at these results, we see that the traditional brainstorming generated a larger number of total, raw brainstorming ideas. Correspondingly, we see that the traditional brainstorming also produced the highest number of valid brainstorming ideas. The peer-review process limited the volume of overall brainstorming ideas and the quantity of valid ideas as well.

Analysis of the difference in noise between the two treatments was performed to determine if the peer-review process reduced the noise in the brainstorming ideas. Analysis indicated that the mean quantity of noise in the peer-review treatment was lower than the quantity of noise in traditional brainstorming but that this decrease was not quite significant.

Examination of the mean quality ratings, creativity and feasibility, for the valid responses indicates that the peer-review system yielded an increase in the average quality of the brainstorming ideas. The treatment condition produced better results for the mean creativity and feasibility scores. Peer-reviewed brainstorming produced a near significant increase in the average creativity rating and a significant increase in the average feasibility rating. These results support the notion that the peer-review process limited the quantity of ideas while increasing the average quality of the brainstorming ideas.

Traditional brainstorming produced higher quantities of overall comments and valid comments as compared with peer-reviewed brainstorming. The review process controlled the brainstorming process and reduced the overall volume of ideas. However, this controlling mechanism also reduced the quantity of high quality ideas as well. The count of high quality ideas was compared between the two treatments. Traditional GSS brainstorming produced higher mean quantities of high creative and feasible ideas. The difference in the quantities of creative ideas was not significant but the difference in the quantities of high feasibility ideas was. Consistent with previous results, the peer-review process constrained the brainstorming process such that the number of good quality comments was significantly smaller than the traditional, control brainstorming treatment. The peer-review process produced fewer ideas overall, fewer valid ideas, and fewer quality ideas. However, the peer-review process did result in fewer lower quality ideas. Traditional brainstorming produced significantly more low creativity and low feasibility ideas than the treatment condition. These results suggest that the peer-review process reduced the quantity of ideas generated by the group, both high and low quality. These results highlight the importance of the context of the brainstorming. In a large group setting, controlling the ideas generated may be appropriate as the number of quality ideas will still be generated. However, in a smaller group, with limited time to brainstorm, the controlling process may be too restrictive, potentially limiting the effectiveness of the group.

Additional analysis was conducted to investigate the impacts of the peer-review process on the participants and their perceptions of the process as compared with traditional brainstorming. The first analysis examined the participants' satisfaction with the brainstorming process. The peer-review condition produced significantly higher process satisfaction ratings than the control condition. Analysis of the participants' satisfaction ratings with the outcome produced a near-significant result with the peer-review process receiving a higher mean satisfaction rating. These results indicate that not only did the extra effort involved with the peer-review process not reduce the satisfaction ratings, but the participants enjoyed the process more than the control condition.

Analysis was conducted to examine the perceived effectiveness ratings between the groups to determine the impact of the peer-review process on perceived effectiveness. The results indicated that there was no significant difference between the effectiveness ratings between the control and treatment conditions. The peer-review groups felt that their brainstorming process, despite the overhead of the review process, was as effective as the traditional brainstorming groups.

Lastly, the perceived measures of participation between the treatments were analyzed. The treatment condition received significantly better participation ratings than the control condition. Being active in the peer-review process yielded increased satisfaction ratings for the participants as compared with free GSS brainstorming. These results are important when considered in light of free riding group members. As mentioned previously, one of the methods for reducing the likelihood of free riders is to encourage active participation within the group’s activities. These results indicate that the peer-review process does a better job of engaging the group members and having them feel like they are actively participating in the collaborative process. Overall, these results indicate that the peer-review process, while creating more work for the group members, does not produce significant negative effects when looking at the perceptual measures gathered in the post-survey. These results lend support to the notion that the peer-review process does not create too much work while increasing the responsibilities of each member of the group.

## 6.2. Experiment 2 – convergence – discussion

This section discusses the findings from the study about groups performing an independent categorization of brainstorming ideas. The goal of this self-directed clustering is to examine how well groups can implicitly coordinate the clustering activity in order to categorize the brainstorming ideas without a facilitator. The process and impacts of this self-coordination aid future development of PD-GSS convergence modules.

The experiment performed for this research compared synchronous groups to groups working in a mock asynchronous environment. The goal of examining these treatments was to further understand the ramifications of moving the group clustering activity from a proximal, synchronous setting to a distributed, asynchronous setting. The results indicate that there were significant differences between the synchronous and asynchronous groups on many dimensions, including time, satisfaction, and quality metrics.

In the synchronous setting, groups completed the categorization task in significantly more time per person than groups in the asynchronous treatment. The difference in average time per person can be attributed to the experimental design and the process loss of working concurrently. First, when working as a group concurrently, differing opinions result in ideas being moved between different categories until some level of consensus or acquiescence is achieved. Likewise, the shared workspace creates conflict when ideas are moving into different bucket and the buckets themselves are being created and altered. The net effect of this changing, concurrent workspace creates difficulties and inefficiencies when working as a group. Second, the experimental design may have induced this effect as groups working in the asynchronous environment will be prone to spending less time per person working on the task due to overall time constraints and motivation. The issues associated with and the ability to use elapsed time as a key metric will be discussed later.

Synchronous groups performed better than the asynchronous groups on the normalized clustering error metric that assessed the quality of the clusters developed by the groups. This metric assesses how many of the brainstorming ideas are correctly grouped together as compared with the categorization performed by an expert facilitator. As with the average time to cluster, the properties of the synchronous environment enabled the group to yield more accurate clusters than groups in the asynchronous environment. The synchronous groups can work more as a team in refining the clusters and providing an improved organization of the brainstorming ideas.

In the asynchronous setting, the participants cannot observe the actions of their fellow group members as they occur. The participants can only work one at a time, constraining ability of each team member to develop a sense of situation awareness and a shared mental model between the each group member. The decrease in situation awareness and social presence hinders the ability of the participants to categorize the ideas. These results show one of the negative side effects of moving from a synchronous to an asynchronous setting.

One of the potential impacts of moving to an asynchronous environment is the lack of groupthink or pressure to conform to the majority of the group. In this type of experimental task, conformance or groupthink may lead to inaccurate clusters. No noticeable signs of groupthink were identified in the data; no benefits were found in moving to the asynchronous environment. Groups in the asynchronous environment had a more difficult time in coming together as a group to identify accurate clusters. These results may stem from the lack of social awareness and context that are not afforded in the asynchronous setting.

Synchronous groups were also thought to potentially be less likely to edit and rename bucket names created by other members of the group due to social pressures and group think, resulting in better results on the bucket change metric. The results indicated that there was no significant difference between the synchronous and asynchronous groups. Synchronous groups were just as likely to edit and revise the buckets as the asynchronous groups. No significant gains were found in moving from a synchronous environment to an asynchronous environment with regard to the level of critical analysis applied to the bucket names themselves.

Synchronous groups exhibited more favorable ratings from the participants in the post-survey. The participants in the synchronous treatment were more satisfied with the categorization process than the participants in the asynchronous treatment. Likewise, the participants in the synchronous treatment rated the experience as being more enjoyable than those in the asynchronous treatment. Two plausible explanations exist for this difference. First, the difference in ratings may be an artifact of the mock asynchronous experimental design. In the asynchronous groups, the participants were required to wait between turns, potentially reducing satisfaction ratings regarding the overall process. Second, the difference may be attributable to the lack of the social interaction between with members of the group. The lack of real-time, visual details of group members contributing to the efforts of the group may produce lower satisfaction ratings as the level of symbiosis or synergy is perceived as being lower. These results highlight the difficulties of maintaining satisfaction and motivation when moving to an asynchronous, distributed environment. Despite the differences in process satisfaction and enjoyment, there was no significant difference between the self-rated measures of satisfaction with the categories developed by the group. Synchronicity did not have a significant impact on the satisfaction with the outcome.

Participants were also asked to rate their perceived level of individual participation and their motivation to categorize well. Participants in the synchronous treatment felt that they were more involved than the participants in the asynchronous treatment. The synchronous participants also reported higher levels of motivation to categorize well. Again, these differences may be the result of two differences between the synchronicity treatments. First, the participants in the asynchronous treatment had to spend time waiting between turns. This wait may play a part in the level of motivation and the perceived level of participation in the task. Second, the lack of more social interaction in the asynchronous groups may limit the feelings of participation and the motivation to participate.

The other treatments in the experiment examined the impact of the quantity of brainstorming ideas that were categorized on the process, outcome, and satisfaction levels. First, the differences in the amount of time required to categorize the ideas as the quantity of ideas increases from small to medium to large were significant. As the number of ideas grows, so does the time required to categorize the ideas. However, the increase is not linear. As the quantity of ideas grows linearly, the time required exhibits more of an exponential increase. This exponential increase can be explained by the level of cognitive effort required to categorize the additional ideas. When more ideas are added to the number of brainstorming ideas, the number of comparisons between brainstorming ideas grows exponentially. For example, if there are ten brainstorming ideas, then each of these brainstorming ideas is compared to the others to identify similar ideas. If the number of ideas is increased by one, the number of comparisons between the brainstorming ideas can potentially increase by up to ten. The addition of brainstorming ideas and the comparisons between them consume attention and cognitive resources, yielding a point at which the resources are constrained and the resulting output suffers. Too many brainstorming ideas may be presented and the efficiency or time required to categorize the ideas will increase at an exponential rate.

The quality of the clusters is significantly impacted by the quantity of brainstorming ideas. The bucket change metric assesses the number of bucket changes over the categorization process. In both synchronicity treatments, the small treatment produced the best bucket change metric as compared with the medium and large treatments. As the number of brainstorming ideas increases, so to do the number of buckets to which they are categorized. As the quantity of buckets increases, it becomes progressively more difficult to edit and revise all of the buckets. The quantity of buckets creates a bottleneck for attention and cognitive resources, limiting the ability of participants to actively edit and refine the buckets themselves. The smaller groups generate fewer buckets, fostering an environment that allows for more critical analysis of buckets and bucket names.

The quantity of brainstorming ideas also had a significant effect on the normalized clustering error metric. This metric assesses how well the groups categorized each brainstorming idea as compared with the facilitator by looking at which brainstorming ideas are associated in the same bucket. In both synchronicity treatments, the medium treatment performed the worst while the small and large groups received the best ratings on this performance metric. One plausible explanation for these results is that the small and large treatments each represent the ends of two different spectra. First, the large groups received the largest number of brainstorming ideas to organize. The quantity of brainstorming ideas enables the participants to obtain a larger perspective of the overall solution space and thus they are better able to define the logical groupings within the solution space. The brainstorming ideas provide more context from which to determine the patterns that exist that may not be evident when fewer brainstorming ideas are available.

This effect may be an artifact related to the experimental design. All of the groups received the same brainstorming ideas to categorize; the ideas were generated by different groups and thus none of the subjects had seen any of the ideas prior to the experiment. The participants therefore had no situational awareness regarding the scope of brainstorming ideas. Had the participants generated the brainstorming ideas themselves, they would have possessed more situation awareness, potentially altering the results found in this research.

The small quantity of brainstorming ideas enables a linguistic parsing of the brainstorming ideas that can be used to group the ideas. The quantity of ideas is so small that the situation awareness is low enough to limit the ability of the group to visualize the solution space and identify logical groupings within that space. The medium category represents the middle of the spectra. There are enough ideas where a strict linguistic parsing becomes difficult and too few ideas to understand the entire solution space, yielding clustering metrics that are worse than the small and large treatments.

As with the synchronicity treatments, the brainstorming idea quantity treatment produced no significant differences between the participants' satisfaction ratings of the categories. The participants' self-ratings of satisfaction with the outcome, clusters generated, were unaffected by any of the treatments within this research project.

The process of group collaboration requires multiple iterations of categorization and refinement to yield quality clustering and a clear, concise set of buckets. The analysis of the flowcharts indicated that the successful groups included more revision and editing steps within their process workflows than the groups that were not successful. This refinement process is analogous to a writing process whereby an author creates a rough draft that is refined and polished during subsequent drafts. When the brainstorming ideas are first categorized, the clusters themselves are often rough and not clearly defined. Subsequent iterations of categorization and refinement are needed to further identify the proper clusters and develop a clear label for each cluster.

The results also indicate the potential benefit of reading all of the brainstorming ideas at the beginning of the collaborative work. By investing the required resources to read the brainstorming ideas, the group can better visualize the solution space and begin creating logical groupings of ideas. Alternatively, if the group does not possess this holistic view of the solution space and begins the clustering process, the ability to identify the logical groupings and accurately cluster the brainstorming ideas is diminished. These results present the possibility that the groups should be required to read all of the brainstorming ideas prior to engaging in any formal activities of creating buckets and assigning brainstorming ideas to those buckets.

## 6.3. Limitations

This research project is subject to several limitations. First, the study utilizes two experiments performed using participants sampled from student populations. The results from these participants may not generalize well to other populations for a number of reasons. The students possess limited experience and knowledge regarding collaborative work in a professional setting. Likewise, the motivation for participation in these studies may not have been high enough to induce high levels of cognitive effort in the experimental tasks. The subjects from the first experiment received class credit for participation while the subjects in the second experiment received extra credit for their participation. Investigation of the quality of the flowcharts from the second experiment indicates that the level of motivation varies considerably from subject to subject.

The first research experiment about peer-review brainstorming consisted of a pilot study to further understand the impacts of one procedure used to control the quality and quantity of brainstorming ideas. The pilot study used a small sample size, limiting the power of the findings. These findings, however, are succinct enough to force alteration of the control procedure in an effort to refine and improve the control process. More details about the subsequent research and refinement of the controlling process are discussed in Chapter 7 under the future directions section.

The second experiment about PD-GSS convergence utilized the average time elapsed per person as one of the metrics analyzed. This metric may not prove reliable in proximal settings where there is no clearly defined end for the participants. Previous research on GSS usage, brainstorming in particular, utilizes experiments where the participants brainstorm for a set period of time. The participants are given a clear cutoff time when the experiment is terminated. Enabling the participants to determine an appropriate end state creates some confusion. The participants frequently asked how long they needed to go to complete the task. Being proximally located, the subjects were highly influenced by each others presence. When the first person from the room completed the assignment and left the room, the motivation to end the task, regardless of the actual status on the overall workflow, increased considerably. The participants in the room may have exerted undue influence on each others choice of when to complete the exercise and to decide that they are satisfied with the group’s outcome. Elapsed time is clearly an important metric in regards to assessing the difficulty of the categorization task and the resources required to accomplish the task. However, this metric may only be suitable to distributed environments where participants are not able to influence each other in this manner.

# CHAPTER 7 – CONCLUSIONS AND FUTURE DIRECTIONS

This chapter concludes the research by presenting a summary of the PD-GSS framework as well as a summary of the experimental results. Implications of this research are discussed and future directions this line of research may take are explored.

## 7.1. PD-GSS summary

The PD-GSS framework presents a shift from the traditional GSS workflow and tools that have yielded interesting research results and have improved group productivity. This section reviews the benefits and impacts of this new framework on the collaborative, group processes.

### 7.1.1. Group decision making

Chapter 1 presented several conditions that are necessary for a group decision-making process to be effective (Surowiecki, 2004). These conditions include the following:

**Diversity of opinion**: Each person should have some private information, even if it's just an eccentric interpretation of the known facts.

**Independence**: People's opinions are not determined by the opinions of those around them. The lack of this independence leads to phenomena such as groupthink that reduce the efficacy of the group.

**Decentralization**: People are able to specialize and draw on local knowledge. Decentralization promotes a diversity of opinion that accompanies independence.

**Aggregation**: Some mechanism exists for turning private judgments into a collective decision. In other words, there must be some mechanism in the group work where each individual is able to voice his or her opinion and the majority opinion is tabulated.

The PD-GSS framework seeks to enhance the benefits to be gained from these criteria by the nature of leveraging potentially large, distributed and asynchronous groups of people. First, by engaging increasingly large groups of people, the diversity of the users of the system should increase commensurately. However, the diversity is predicated on the context within which the GSS tool is used. If used within a large organization, by employees of a particular position, the amount of diversity may not be as significant. Second, PD-GSS seeks to enforce independence by providing anonymity at all times throughout the collaborative process. When working in a distributed context, this anonymity is ensured as the only group interaction takes place via anonymous text-based communication. Participants cannot tie comments, ideas, or suggestions to any one particular person throughout the collaborative tasks. This improvement in absolute anonymity encourages more diverse thought and less groupthink.

Finally, the nature of the PD-GSS categorization process fits the described requirements for aggregating individual’s opinion into a group consensus. Individuals can provide their input as to the major threads or buckets within a solution space. The PD-GSS tool provides the necessary framework to harness these opinions and create a composite that represents a consensus from the group. This aggregation is made possible through the autonomous and anonymous nature of the PD-GSS workflow.

### 7.1.2. Process gains and losses

The PD-GSS framework impacts the productivity gains and losses that arise from group work. The process gains and losses associated with PD-GSS are compared with a typical GSS in this section.

As mentioned previously, the PD-GSS architecture enables parallel communication and parallel processing throughout the collaborative workflow, resulting in several process gains. This parallel work is especially important in the categorization process, as individuals can provide work for the group and work in parallel. This parallel processing enables more participation from the group members as compared with traditional GSS groups. Traditional groups require the use of expert facilitators to guide the categorization process in a serial nature. This serial process reduces the ability of each member of the group to be actively engaged in the process. PD-GSS increases the parallel processing capabilities of the group, increasing individual participation and communication.

PD-GSS provides for complete anonymity throughout the entire collaborative process. This anonymity is a requirement in distributed, asynchronous environments. Traditional GSS sessions require verbal interaction and communication during various phases of the collaborative efforts. This verbal interaction can compromise anonymity and the benefits associated with it. PD-GSS provides mechanisms where all interaction and group communication is accommodated through the text-based PD-GSS system.

The combination of comprehensive parallel processing and anonymity create an opportunity to achieve further benefits as a group as compared with traditional GSS groups or even nominal groups that are not supported by technology. The anonymity throughout the process creates an environment for more objective evaluation of brainstorming ideas and potential solutions. Individuals can contribute ideas, critique existing ideas, categorize ideas into buckets, and vote on ideas without fear of public reprehension or other social ramifications. Group members are stimulated by the increased flow of information and higher level of participation, resulting in an increased level of synergy for the group.

The PD-GSS framework also changes some of the process losses as compared with traditional GSS. First, there is a reduction in the attention blocking process loss. PD-GSS encourages the participants to be actively engaged in the process through parallel processing, mitigating the traditionally serial portions of the GSS workflow. Each participant is able to contribute freely to the collaborative work.

One of the largest problems associated with GSS usage as compared with nominal, non-technology supported group work is that of free riding or social loafing. The benefits of anonymity can be negated by the ability of participants to disconnect from the group work process. The PD-GSS framework exacerbates this problem when individuals are working in a distributed environment. Motivation for the participants to log into the system and actively participate in the group effort becomes of primary importance.

However, PD-GSS contains some attributes that may provide incentives for the group members to stay actively engaged. As stated previously, one of the methods to overcome free riders is to actively engage the participants in meaningful tasks. PD-GSS encourages the group members to be actively engaged, providing an environment where they can work autonomously and anonymously at any time. There are no serial processes where the participants must sit and observe the collaborative work. PD-GSS pushes responsibility and action to the members of the group. This responsibility potentially increases the level of engagement of each group member during the collaborative work.

One additional method to reduce the likelihood of free riding is allowing the group members to choose their task. In the PD-GSS framework, at any point during the collaborative workflow, there may be two to three collaborative modules that are open and can be worked on. As the user logs into the system, a choice may be presented to the group member, allowing the individual to select which activity or module to work in. This selection process allows for more flexibility for the end user, potentially improving motivation to use the system and to be part of the collaborative effort.

The last two process losses addressed here are information overload and the incomplete use of information. These two process losses are highly correlated and will be discussed together. First, as noted previously, GSS usage can increase the volume of information shared between members of the group. The end result is a situation in which too much information is presented, potentially stifling the group from information overload. As the volume of information grows, the percentage of information that is used by the group may begin to decrease commensurately as the group reaches limits imposed by time and cognitive constraints. PD-GSS seeks to improve this scenario in the brainstorming process by controlling the volume and potentially quality of the brainstorming ideas. More refined brainstorming ideas are submitted, resulting in two benefits: minimizing the volume of “noisy” solutions and improving the clarity of brainstorming ideas. The end result is a set of brainstorming ideas that require fewer resources to process and synthesize. This impact will become especially noticeable as the size of the group grows.

### 7.1.3. Team Theory and PD-GSS

Much of the PD-GSS framework is rooted in the underlying principles of Team Theory. This theory posits that human attention resources are the constraining factor in group tasks. The availability and effective leveraging of these resources significantly impacts the productivity level of the group.

Team Theory posits that the cognitive efforts of each member of the group must be subdivided over three competing tasks: communication, information access, and deliberation. These three tasks are all required components in a group setting but each consumes finite cognitive resources at a detriment to the other processes.

PD-GSS seeks to improve the collaborative process such that it can be successfully executed in a distributed, asynchronous environment. One of the foundations of PD-GSS is the harnessing of individual skills and abilities to drive the collaborative work. Group members are tasked with more responsibility and work as compared with previous GSS workflows. The difficulty becomes providing enough responsibility to engage the participants while not overloading and consuming all the cognitive resources. To ameliorate the potential overload, PD-GSS presents the collaborative tasks to each group member in discrete units of work. These segments of work are based off of the particular modules that are requiring work within the overall workflow. The user is either assigned to a module or selects the module from a menu. The user can then provide the work associated with this module (e.g., brainstorming or clustering brainstorming ideas for a set period of time). Users can complete as many discrete modules as time allows. This approach seeks to decompose the overall collaborative process into manageable pieces that are more flexible and less overwhelming.

Many of the design features of PD-GSS seek to improve the information access process during the collaborative tasks. This research seeks to improve the ability of each member of the group to share and obtain information that is relevant to the task. For example, in the brainstorming or divergence activity, each member of the group can contribute new ideas or information for consideration by the group. This research seeks to control the brainstorming process, refining the brainstorming ideas as they are submitted to the group. The end result of this process is a set of brainstorming ideas that consist of fewer “noisy” brainstorming ideas and are of higher quality. This higher quality includes such factors as quality of writing. Reducing the quantity of noise that the members must process and improving the readability of the brainstorming ideas, PD-GSS reduces the cognitive resources required to access and process the new information. The group can process more and higher quality ideas than with an uncontrolled brainstorming process.

The PD-GSS process of convergence also provides for improvements in the efficient use of cognitive resources. During the categorization process, individuals receive subsets of the entire set of brainstorming ideas and identify logical groupings or clusters of ideas. The effect is to create subsets of ideas that need to be organized, reducing the cognitive load associated with synthesizing large groups of information at one time.

PD-GSS seeks to develop group support tools in such a way as to utilize the collective abilities and resources of the collaborators better. Improving the information that is gathered as a group and the way in which it is organized plays a significant role in moving toward increased efficiencies with regard to and eventually optimization of their limited cognitive and temporal resources.

## 7.2. Summary of results

Additional work is required to refine the peer-review process to increase the productivity of the controlled brainstorming process while still minimizing the volume of noise and low quality ideas that are entered into the brainstorming system. The overall objective of controlling the brainstorming process is valid but the means to control the process needs refinement. Additional ideas for means to control the brainstorming process are presented below in the future research section.

The results of the categorization experiment indicate that groups working with the fewest brainstorming ideas can provide the most accurate clustering and critical analysis of the buckets. The smaller quantities of ideas produced an environment that enabled the group members to review and edit the buckets, improving the output generated by the groups.

Finally, groups that read all of the brainstorming ideas at the beginning of the experiment and performed specific reviewing steps within the workflow performed better than those groups that did not. These results highlight the complexity of the categorization process and the potential gains to be achieved from subdividing the complex task into simpler, discrete subtasks. Future research directions are outlined below.

## 7.3. Contributions and implications

This section highlights contributions made by the present research and the implication that these results have for researchers, practitioners, and Group Support Systems software designers.

The PD-GSS framework presents a different approach to extending the power of group work and collaboration to asynchronous and distributed groups. Traditional GSS processes and technology were designed to be used primarily by proximal, synchronous groups. The same workflows and processes may not perform well in a distributed setting where the facilitator is not able to exert as much control over the group. PD-GSS enables more flexibility for group administrators or facilitators to execute collaborative work in various contexts. The new framework enables groups to collaborate when proximal, synchronous meetings are not feasible.

PD-GSS include significantly more complexity than traditional GSS systems. In traditional GSS workflows, each collaborative activity is performed serially and does not utilize concurrent activities. PD-GSS includes a dynamic workflow where modules may be worked on concurrently. This dynamic workflow presents an additional layer of complexity as the interaction between modules must be seamless and completely transparent. One example of this more complex interaction between collaborative modules is the relationship between the brainstorming and categorization modules. In traditional workflows, the group finishes the brainstorming activities and the entire set of brainstorming ideas generated is transferred to the categorization module. In the PD-GSS workflow, the ideas from the brainstorming activity must be transferred at more frequent intervals between the two modules. As participants are clustering while others are brainstorming, new ideas generated must be moved to the categorization modules to be worked on. The system must be created in such a manner to facilitate this data sharing between the modules.

The creation of PD-GSS systems presents certain challenges to the PD-GSS researcher. The framework advocates asynchronous, distributed work. This type of context represents numerous challenges to researchers looking to examine this framework in laboratory experiments as there is not currently much in the literature regarding asynchronous experimentation. Proper methods, metrics, and experimental design must be developed to enable meaningful results to be derived from these experiments due to the lack of control over the participants and their environment.

The results from the two laboratory experiments provide support for the PD-GSS framework and the consensus-based approach to asynchronous, distributed collaboration. The results from the brainstorming experiment provide support for the PD-GSS feature of a controlled brainstorming process to limit the volume of noise within the system. The amount of low quality ideas were reduced within the peer-review brainstorming environment as well as the overall number of ideas generated.

The PD-GSS framework seeks to decompose the convergence process into various sub-processes. The results from the second experiment provide support for this position. The groups that were able to understand and execute the various sub-tasks involved in categorizing the brainstorming ideas performed better than those that did not. Decomposition of the process will further enable the participants to better focus on a single stated objective and simplify the overall convergence process.

## 7.4. Future directions

The results from the peer-review brainstorming experiment indicate the potential benefits of controlling the brainstorming process. The specific implementation of the means to control may not be perfect and other options exist that may improve the productivity of the group.

One alternative means to controlling the brainstorming process is to adjust who is performing the actual edits to the original brainstorming idea. Some of the qualitative feedback received from the experiment indicated that the participants, at times, had difficulty deciphering the meaning, intent, or scope of certain brainstorming ideas. Difficulties stemming from differences in terminology and writing coherence hinder the ability of the peer reviewer to decode the proper meaning of the original message in order to improve upon it. It is certainly possible to speculate as to the meaning of these comments but that may increase the risk of the original brainstorming idea becoming buried and never seen by the group. For this reason, one alternative is to have the peers review the original brainstorming idea, similar to a peer-review process for submitting papers to a journal. The peers have an opportunity to ask questions about such things as meaning and scope. These comments are then returned to the original author, who has the opportunity to edit the original brainstorming idea to resolve the concerns of the reviewer. This mechanism provides the same controlling mechanism to improve the coherence and quality of the brainstorming ideas. However, the original author is still responsible such that his or her thoughts and intent are hopefully clarified and enhanced. This review process enables ideas that are "diamonds in the rough" to be further polished and refined rather than being removed from consideration altogether.

Subsequent research needs to examine the impact of different means of controlling the brainstorming process. This additional experimentation needs to encompass differing contextual factors, including group size and synchronicity. It is plausible that the true benefits from a controlled GSS brainstorming process will only be evident once the size of the group surpasses a specific threshold.

The second experiment investigated the ability of groups to independently cluster brainstorming ideas. This is the first step to implementing a functional PD-GSS, distributed clustering prototype. Several key experiments need to be analyzed to further the line of convergence research. The first experiment should investigate the possibility of decomposing the entire set of brainstorming ideas into discrete portions. The experiment would investigate the ability of groups to categorize the entire set of brainstorming ideas at once versus clustering a subset of the ideas, repeating the clustering until all of the ideas are categorized. For example, the control group would cluster the entire 120 brainstorming ideas at once. The treatment group would have the groups cluster 30 brainstorming ideas. Once these ideas are categorized, an additional

30 ideas would be presented to be categorized. This process would be repeated four times, until all 120 ideas are categorized.

This type of approach investigates the feasibility and potential impacts of decomposing the entire brainstorming idea pool into subsets. It is plausible that the decomposition will enable the participants to better cluster, edit, review, and modify the clusters as compared with groups that are forced to work through all of the brainstorming ideas at one time.

One key metric of this study would be the impact on participant satisfaction ratings over the duration of the experiment. As illustrated in Figure 4, satisfaction ratings drop significantly during the convergence activity. The subjects need to be polled over small increments of the entire process to gauge the satisfaction ratings over the entire process. Gathering the ratings throughout the experimental task could be accomplished by integrating the ratings into the GSS tool itself. At set intervals, the GSS tool presents a window where the participants are required to quickly enter a satisfaction rating on a Likert scale. This method of gathering the data would ensure that the ratings are completed and are done in a timely manner. This trend information could then be used to plot the impact of the modified convergence process over the clustering lifecycle.

The results of the experiment indicate that many benefits are apparent in the small and medium size brainstorming idea treatments. Further research needs to investigate midpoints between the current brainstorming idea quantities to examine the impact of these midpoints. For example, instead of three brainstorming idea sizes, five could be used, augmenting the small, medium, and large buckets with two midpoints. Using the current experiment as a guideline, the brainstorming quantities would be 30, 50, 70, 90, and 110 brainstorming ideas. The results of this experiment would serve to clarify the benefits of clustering different quantities of brainstorming ideas at a time.

The next experiment should examine the possibility of decomposing the categorization process down into discrete subtasks. The treatment could create three distinct subtasks that the group must complete as part of the experiment. The first step would be to read the entire set of brainstorming ideas. The second step would be to complete a first pass at the categorization. The third steps would be an explicit process to review and edit the categorization scheme. This final step is posited to improve the accuracy of the clusters and potentially reduce the reluctance to anchor on the initial buckets. Additional subtasks could be incorporated into the experimental design. For example, explicit steps could be implemented where the participants review clusters to identify large clusters that need to be decomposed or clusters that need to be consolidated. This treatment would be compared against a traditional categorization activity where the participants are free to categorize, and utilize the three steps, however they see fit.

The next set of experiments seek to further understand the PD-GSS approach by creating an experimental design that is more realistic to actual PD-GSS usage. First, an experiment needs to be conducted to examine the ability of groups to perform the categorization task in a truly asynchronous environment. Research needs to be conducted to understand the consequences of moving to a truly asynchronous environment. Can the groups complete the assigned task? Is there more critical analysis and less group think than in synchronous environments?

Second, experiments need to be run that examine the ability of the PD-GSS framework to accommodate overlapping activities. For example, have the group start brainstorming for a specified period of time. Toward the end of the brainstorming session, enable the participants to choose which activity they would like to work on, brainstorming or categorizing. This treatment needs to be compared with a traditional brainstorming workflow where the activities are performed serially and with no overlap. This experiment examines the impact of a more dynamic PD-GSS workflow with a traditional GSS workflow.

The final set of experiments seeks to understand the potential integration with PD-GSS convergence and automated clustering techniques. The experiments need to analyze the potential benefits and synergies from leveraging the strengths of both the participants and the automated algorithms. The control treatment would perform the categorization without any aid from the automated clustering algorithms. The treatments would receive a first cut listing or straw man of categories as generated by an automated clustering algorithm. The straw man provides an initial categorization scheme from which the groups start refining and completing the categorization process.

The impact of the automated clustering algorithms can be examined through the use of both good and bad straw men. A list of good preliminary buckets can be provided to a group to contrast with a group of poor preliminary buckets. The study will examine the potential of the group to overcome the poor initial clustering or if the anchoring bias restricts that correction. This study highlights the potential benefits and drawbacks of a combined automated and PD-GSS workflow.

Lastly, many experiments need to be performed to investigate potential alternative communication channels that are available to a group during the clustering activity. Moving from a synchronous, proximal environment where the participants can discuss ideas and resolve issues to an asynchronous environment where this oral communication is not available limits the effectiveness of the groups. Alternative channels of communication need to be examined that enable the distributed, asynchronous groups to further collaborate and improve their shared mental models. These channels of communication do not necessarily mean interactive communication but may also take the form of messages to explain certain actions or provide additional reasoning or context.

# APPENDIX A – PEER-REVIEW BRAINSTORMING SCREENSHOTS

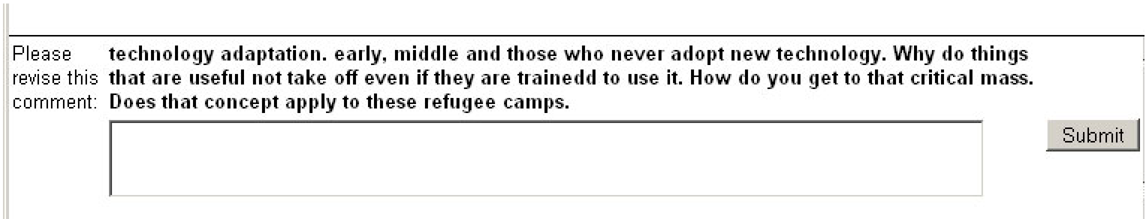


Figure 17: Peer reviews the original brainstorming idea

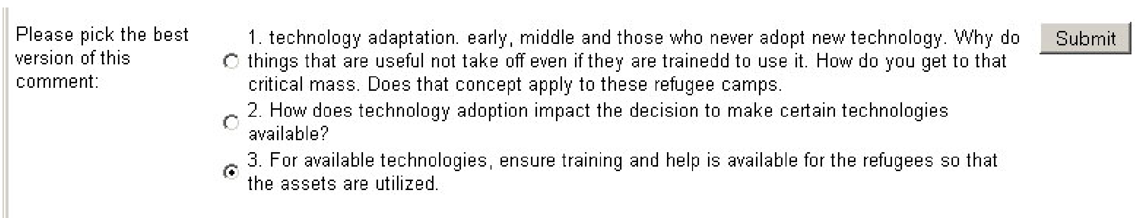


Figure 18: Peer selects the best alternative

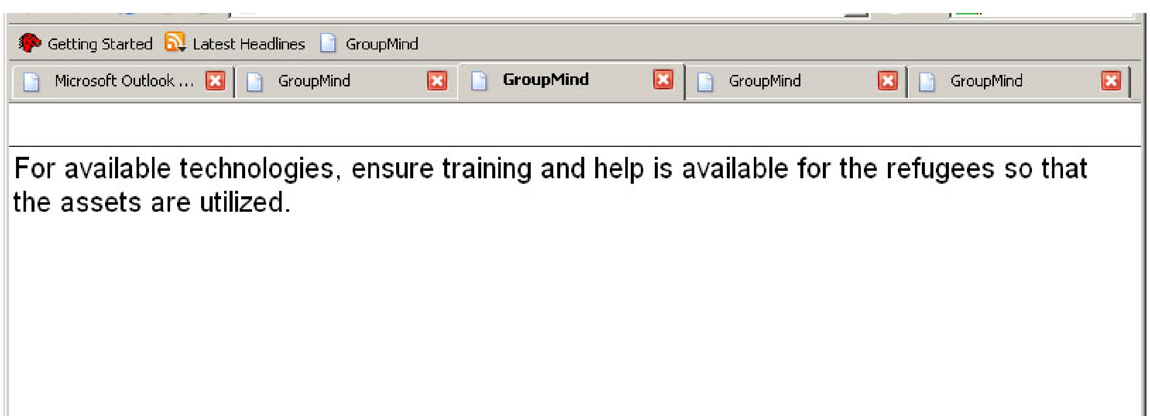


Figure 19: Best version of the brainstorming idea is displayed to the group

# APPENDIX B – THE SCHOOL OF BUSINESS TASK INSTRUCTIONS

*Disclaimer: This scenario is fictitious. Any resemblance to real organizations is purely coincidental.*

To: Undergraduate Policy Committee

From: Provost

Re: 5 Year Business School Policy Recommendation(s)

Your committee, the Undergraduate Policy Committee, is charged with setting policies for the School of Business and Public Administration (BPA). We have been receiving complaints about problems in the BPA: limited BPA physical resources, low quality instruction, students who are ill prepared, limited computer resources, a declining reputation of the school, and others. While I believe that the bulk of these complaints may be unfounded, I'd like your committee to look into it, determine what problems exist, and set whatever policies are necessary to correct the problems you identify. You have complete authority to make policy changes.

I have attached a summary sheet of problems reported during interviews with the following individuals on campus:

- Associate Dean of the School of Business and Public Administration
- President of the Business Student Council
- President of the University Business Alumni Association
- Vice President of University Undergraduate Instruction
- Chairperson of the Faculty Council

Each of you is uniquely qualified to contribute to this effort and represents an important interest group within our university community. Please work together, giving one another the benefit of your knowledge, your experience, and your perspective. Each of you should carefully consider how any proposed policy changes might affect each of the interest groups indicated above. Together you should seek solutions that accommodate everyone's needs. After deliberating on these issues, I will see that your recommendations are implemented.

I have complete confidence in your ability to complete this important task. Be bold, be creative, and be direct.

**Quotes Obtained During Job Performance Evaluation Interviews**

"I sure would like to stop my senior faculty from resigning! I need them to bring in grants with the research they perform. I don't think everyone realizes what a dramatic impact this has on the quality of education for our students." **Associate Dean, BPA**

"With impending University budget cuts, we'll be lucky to maintain our professor's current salary levels. What else can I do to compensate them?" **Associate Dean, BPA**

"If tuition goes up again, I'll have to get a part time job in order to afford it! That means it will probably take me an extra year to graduate!" **Student Council President**

"Access to the Internet is difficult as the wireless Internet and lab space is limited." **Student Council President**

"I'm tired of taking classes from Teaching Assistants. They just don't seem to have any real experience to help us understand the lecture material like the professors do. Many students are now taking longer to graduate because they are being careful to only take classes taught by actual professors instead of TAs." **Student Council President**

"It is harder and harder to find job placement for our graduates these past few years. The market is becoming saturated with lower quality graduates. It seems that our reputation for research and student instruction have been receiving some bad press lately. If our image continues to slip, we will soon have a real problem to deal with." **Alumni Association President**

"A few prospective employers that I have talked with lately are under the impression that our recent graduates lack critical thinking and problem solving skills, not to mention their poor oral and written abilities. Others have commented on a lack of practical experience in our graduates." **Alumni Association President**

"Maintaining the quality of my courses is becoming more and more difficult. There is also increasing pressure from the administration to offer higher quality instruction. If the stress level isn't reduced around here, I might start looking for another job!" **Faculty Council Chairperson**

"I'm very worried about my upcoming tenure application! Several faculty have already been told that they aren't publishing enough research. And now the administrators want us to participate in more committees? It's becoming very difficult lately!" **Faculty Council Chairperson**

"I've been here a long time, and lately I'm getting fed up with students that are just plain ill-prepared for their coursework! Couple this frustration with no raises over the past few years and it's no wonder that seasoned faculty are leaving!" **Faculty Council Chairperson**

"Faculty evaluations over the past few semesters have shown a definite downward trend. Also, none of our students seem to be interested in our Friday evening or weekend classes." **Vice President of Undergraduate Instruction**

"It is very difficult to be the champion of affirmative action programs around here. I keep getting beat up by the administration for not giving enough priority to in-state students." **Vice President of Undergraduate Instruction**

"News from the governor's office indicates that state funds for higher education will be capped and possibly cut in coming years. Other administrators insist there just isn't money for new buildings." **Vice President of Undergraduate Instruction**

Associate Dean:
No more money
Senior Faculty Quitting

Student:
Tuition is high
Internet access
Classes too big
Not enough classes offered
Too Many raw TAs

Alumni President:
Reputation Declining
No demand for majors
Poor quality graduates

V.P Undergrad Affairs:
No more classrooms
Admission standards too low
Graduation rate too high
Minorities under represented

Faculty Rep:
Classes too big
Overwork and burnout
Resignations

- Reduced research
- Reduced grants
- Poor teaching

Students Ill prepared

- Math
- Problem-solving

# APPENDIX C – EXPERIMENT 1 – DIVERGENCE – EXPERIMENTER SCRIPT

**Experimental Checklist for the School of business Task**

1. Make sure you have at least 30 of each of the following:
    a. Task information sheet
    b. Random number / Username cards
    c. Pre and Post surveys
2. Completely power down and restart all workstations in the room.
3. Log each workstation into Windows using the default login for that specific workstation (usually on the sticker on the monitor).
4. Open Mozilla Firefox and make sure the homepage is set to the following address:
    a. http://pdgss.cmi.arizona.edu/start.html
5. Hand out cards in random order for the groups. Each group should have 6 people in it. Make sure the groups have at least 5 members in them. If there are extra people, the task can accommodate up to 7 people.
6. Load the Task information Powerpoint on the facilitator's computer (control or treatment).
7. Log into GroupMind and into the Sample brainstorm meeting
8. Leave copies of consent form and index card on each desk ahead of time.
9. Start the session by introducing yourself, read directly from the script.
10. Allow groups to brainstorm for a period of exactly 20 minutes.
11. Warn groups when they reach the last minute, give 30 seconds for them to finish their last solution.
12. Make sure we get all task sheets and all surveys returned before everyone leaves.

**BEGIN FACILITATOR SCRIPT**

[Start Powerpoint show for task information at the facilitator's computer, show Welcome slide]

[Hand out random Username cards]

Hello. My name is <facilitator name>. Let me start by thanking each of you for coming. We need your help, and we appreciate your taking the time to come. If you haven't already done so, please take a moment to read and click on the Accept button on the participant consent information on your computer. Also, please hold on to the index cards for just a few minutes.

Usually I'd just talk to you, but today I am going to read from this script. There'll be a lot of people like yourselves helping us with this experiment, and for the sake of science we have to make sure that everyone starts with exactly the same information.

Welcome to the University of Arizona's GroupSystems room. This room is the product of theories and technologies that allow a group such as yours to solve problems much more quickly than a conventional meeting would allow. We conduct research comparing these technologies to each other. Today, you will be using just <u>one</u> of these technologies.

We really appreciate you coming to help us today. Your efforts will guide us as we direct the future development of this technology. Your work today is very important to us.

Today, you will work together as randomly designated teams of six people each to decide how best to solve a problem. To help you generate your solutions to the problem, you will be using electronic meeting tools that are designed to support electronic brainstorming groups. Brainstorming is a way to generate a lot of solutions in a very short time.

****START FREE BRAINSTORMING (CONTROL) DIRECTIONS *****

The process is simple. Imagine each of you started with blank sheets of paper in front of you. When I say go, each of you will write one solution on a piece of paper, and then throw your paper on a pile in the middle of the room.

Electronic brainstorming is like this. When you have finished typing your solution, click the 'submit' key to send your solution back to the group. Your comment will be added to the list of comments generated by the group, for all to see. We will continue in this fashion for 20 minutes. To give you a better understanding of electronic brainstorming, I will show you a quick example.

[Switch to Example brainstorming meeting. Enter one or two new comments.]

****END FREE BRAINSTORMING (CONTROL) DIRECTIONS *****

****START PEER-REVIEW BRAINSTORMING DIRECTIONS *****

The electronic brainstorming system we are going to use utilizes a peer-review system to help in refining brainstorming input. This is a system where once you enter a new brainstorming idea, the idea is reviewed and updated by two random peers in your group. The goal of the reviewer is to create a more cohesive and coherent version that is easier to read and understand. A 4th member of your group then selects the best version of the comment. The ‘best’ version is then available for all members of your group to see. All of this process is anonymous and random.

[Advance slide to Peer-review graphic and point to the steps in the graphic while reiterating the following]

The original brainstorm idea is entered into the system. This new brainstorming idea is then routed to two additional people for review editing. A fourth individual is then responsible for choosing the best version that is submitted for the entire group to see.

[Show slides illustrating the process]

If there comes a time that you do not have anything new to add to the brainstorming session, you can click on the “Review Brainstorming” button to see if there is reviewing work to be done instead.

[Log into Sample meeting and illustrate the Review Button and the brainstorm process.]

We will brainstorm in this fashion for 20 minutes.

****END PEER-REVIEW BRAINSTORMING DIRECTIONS *****

***** BRAINSTORMING DIRECTIONS FOR EVERYONE *****

Once a brainstorming idea is entered into the system, you will notice there is a place for you to rate each idea on two categories: creativity and feasibility. Creativity refers to how innovative the idea is while feasibility refers to the extent to which the idea can be implemented easily. Please select a 1 to 5 rating for each idea then click the button to submit your ratings. After you have submitted your ratings, you will see a graphic illustrating the composite score for each idea.

[Demonstrate rating on sample meeting]

Does everyone understand how this works? Are there any questions on how this procedure works?

[Answer any procedural questions at this point]

Today, your primary task will be to work together as randomly designated teams consisting of 6 people each to decide how best to solve the problems for the School of Business.

Each random group of 6 will act as the University policy making committee and will have complete authority to specify exactly what actions should be taken to resolve the problems. You will have complete control.

The memo you are about to receive contains a list of quotes obtained by the Provost during performance evaluation interviews with a number of key representatives here on campus. Each quotation exemplifies one or more key concerns or problems that each of these individuals has identified during the course of their jobs. What we need is for you, the policy-making committee, to work together and to solve as many of these problems as possible.

At the end of today's session, your solutions will be given to the Provost, who has agreed in writing to implement all of your recommendations. Your committee has been given complete power to solve the identified problems. Remember that your goal is to solve the problems of the School of Business and Public Administration.

We're going to give each of you a copy of the Report now. You'll have a few minutes to review it. Feel free to ask any questions that come up while you read.

[Hand out the task sheet and give everyone a few minutes to read it]

Has everybody finished reading the report? Are there any questions about the report?

**Q:** What kind of resources/material/people/etc. are available for this task?
**A:** Whatever you think is appropriate given what you have read.

Today you are going to generate solutions in the form of recommendations that will be given to the University Provost. Be sure to focus your solutions on specific actions you have decided the university must take to solve its problems.

Your goal is to identify as many different solutions as possible in a short amount of time. So we urge you to concentrate on generating new solutions. Try not to repeat yourself. Just state your case and move on; don't get bogged down arguing the same point over and over again. Right now, your goal is to generate as many different solutions as possible that will solve the problems of the School of Business and Public Administration. You will have twenty minutes to generate your solutions.

There is one important limitation to the solutions you propose: Each solution you type is limited to a maximum of 3 to 4 lines of text. This restriction is intended to help you keep your solutions short and to the point.

Everything you type in electronic brainstorming will be anonymous. No one will be able to tell who said what. This makes it possible for you to concentrate on generating solutions, without worrying about personalities and politics.

Are there any questions at this point? [Wait for a few minutes]

You have in front of you a copy of the most recent report on the situation. Look for solutions that solve as many of these problems as possible. You are encouraged to refer back to this report as you work.

Is everyone OK with this?

[Show Brainstorming Task slide]

After accepting the consent information, you will be sent to a log on page for the brainstorming system. Please log into the system using the username that is on the card by your computer. The username is case sensitive and there is no password. Do NOT begin brainstorming until I tell you to begin.

Has everyone logged into the system okay?

[Make sure everyone has accepted the consent and is successfully logged into GroupMind]

We are now ready to begin the task, and we'll do it just like we did before. You will type in a solution and click the submit button. Please start brainstorming now.

[Start the timer for 20 minutes. Warn the groups when there is 5 and 1 minute left]

OK, our time is up. Why don't you finish typing the solution you are working on, and press submit to send it to the group, then we will move on to the final phase.

[Wait for typing to stop]

Before we go any further, we need your cooperation in one more important way when you leave. People will ask you what happened here, but please don't tell them anything about the technology or the task until the end of the semester. That would spoil our results with the rest of the people who are helping us learn about this technology. It would give us inaccurate results.

Finally, we want to give you a short questionnaire where you will be able to tell us about how this session has gone. Your thoughtful and honest responses will help us shape the future directions of this technology.

[Provide URL to the group: http://pdgss.cmi.arizona.edu:8001/s3/Survey?survey3file=Post ]

Thanks for your feedback on the survey. It will be a big help to us. When you have completed your survey, please just bring all your papers (consent form, username card, and task information sheet) to the front. Thanks for coming!

[Make sure to get the task sheets back from each subject]

# APPENDIX D – EXPERIMENT 1 – DIVERGENCE – POST-SURVEY

1. How much exposure have you had to this type of University situation?

   1-2 times    3-5 times    5-10 times    10+ times    None

2. I have personally experienced one or more of these same problems:

   no    yes

3. How realistic are the problems of the School of Business?

   | 1 | 2 | 3 | 4 | 5 |
   |---|---|---|---|---|
   | very realistic | | neutral | | not at all realistic |

4. How difficult did you find this task?

   | 1 | 2 | 3 | 4 | 5 |
   |---|---|---|---|---|
   | not at all difficult | | neutral | | very difficult |

5. How engaging did you find this task?

   | 1 | 2 | 3 | 4 | 5 |
   |---|---|---|---|---|
   | very engaging | | neutral | | not at all engaging |

6. The meeting methods we used today (did not meet - met) my expectations:

   | 1 | 2 | 3 | 4 | 5 |
   |---|---|---|---|---|
   | met | | neutral | | did not meet |

7. Today's meeting process was (inadequate - adequate) to meet our goals:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| inadequate | | neutral | | adequate |

8. How satisfied were you with the process we used today?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| satisfied | | neutral | | dissatisfied |

9. The outcome of today's meeting is:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| satisfactory | | neutral | | unsatisfactory |

10. Thinking about the tools and methods we used today:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| I prefer other tools and methods | | neutral | | I prefer today's tools and methods |

11. How do you feel about the process by which you generated solutions?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| dissatisfied | | neutral | | satisfied |

12. How do you feel about the solutions proposed?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| dissatisfied | | neutral | | satisfied |

13. Overall, how enjoyable did you find your experience?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| not at all enjoyable | | neutral | | very enjoyable |

14. How effective was your group at generating solutions?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| not at all effective | | neutral | | very effective |

15. How much do you feel you participated in this idea generation session?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| not very much | | neutral | | a great deal |

16. How motivated were you to generate good solutions?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| very motivated | | neutral | | not at all motivated |

# APPENDIX E – EXPERIMENT 2 – CONVERGENCE – EXPERIMENTER SCRIPT

**Experimental Checklist for the School of Business Task**

13. Make sure you have at least 30 of each of the following:
    a. Task information sheet
    b. Participant ID cards
    c. User name and passwords at each workstation
    d. Paper for flowcharting
    e. Pre and Post surveys
14. Write URL of post-survey on the whiteboard
15. Write the following steps on the whiteboard and label as itinerary:
    a. Categorize brainstorming ideas
    b. Log out of system
    c. Flowchart process used
    d. Complete post-experiment questionnaire
16. Completely power down and restart all workstations in the room.
17. Log each workstation into Windows using the default login for that specific workstation (usually on the sticker on the monitor).
18. Load the Facilitator's Powerpoint on the facilitator's computer
19. Log into Thinktank and into the Sample brainstorm meeting
20. Leave copies of participant ID cards, ThinkTank info, and SOB case on each desk ahead of time.
21. Start the session by introducing yourself, read directly from the script.
22. Make sure we get all task sheets and all surveys returned before everyone leaves.
23. After everyone leaves, record the elapsed time that each person was in ThinkTank, do one final export of the meeting, and reset the brainstorming ideas to the uncategorized bucket

**BEGIN FACILITATOR SCRIPT**

[Start Powerpoint show for task information at the facilitator's computer, show Title slide]

[Hand out random Participant ID cards, ThinkTank info cards, and the SOB case]

Hello. My name is <facilitator name>. Let me start by thanking each of you for coming. We need your help, and we appreciate your taking the time to come. If you haven't already done so, please take a moment to read and click on the Accept button on the participant consent information on your computer. Then answer the few brief demographic questions. Please hold on to the cards for just a few minutes. You will need that information later.

Usually I'd just talk to you, but today I am going to read from this script. There'll be a lot of people like yourselves helping us with this experiment, and for the sake of science we have to make sure that everyone starts with exactly the same information.

[Show Objectives slide on PPT]

Today you will be organizing the brainstorming ideas from another group. In a group session like this, a group first brainstorms ideas to solve a problem. These ideas must then be organized into categories or buckets. These categories are then used to focus on the areas that are the most important.

[Show slide of ThinkTank categorizer]

The buckets make it easier to work with the ideas since there will be significantly fewer buckets than brainstorming ideas. The buckets are voted on to find the most important buckets and the group then develops action plans to implement the ideas. For this reason, the buckets need to be clearly worded and accurately represent the underlying brainstorming ideas.

[Show slide of brainstorming ideas]

This is a sample of brainstorming ideas for how to improve an MIS program. Looking at these ideas, we can see that there are some common themes or categories for these ideas.

[Advance slide]

These two ideas, highlighted in yellow, relate to the registration process. Therefore, they could be put in the same bucket about registration procedures.

[Advance slide]

These three brainstorming ideas relate to the use of computer labs within the department or school of business. They could be grouped into a category about access to lab resources.

Group support systems, the tool you are about to use, enables groups to work to brainstorm and organize the brainstorming ideas into buckets. To illustrate how this works, I will show you the application you are going to use.

[Get on the Sample Thinktank meeting.]

First, clicking on the 'uncategorized' bucket will show you all the brainstorming ideas (on the right) that need to be categorized. This means they still need to be put into an appropriate category or bucket. The buckets will be listed on the left side. Two things to note: First, you can resize the columns by clicking and dragging. This way, you can see the bucket name better [Demonstrate column resizing]. Also, you will see that comments with a lot of text show a little silver box. Clicking on the box will show you the entire contents of the comment. [Demonstrate clicking on the box.]

You can add buckets, rename buckets, and delete buckets. To put a brainstorming idea into a bucket, you simply click and drag the idea into the bucket.

[Demonstrate these different functionalities. Create two buckets for the lab and registration ideas. Demonstrate a good name and a bad name for the buckets.]

You will see that the name of the bucket is very important as it lets the group quickly summarize the brainstorming ideas behind it.

It should be noted that if you delete a bucket that has brainstorming ideas in it, the idea is deleted as well. For this reason, be very careful when deleting buckets. Be sure to move the brainstorming ideas to another bucket first.

Are there any questions about how this system works or the objective of the experiment?

****START ASYNCHRONOUS DIRECTIONS *****

Today you are going to simulate an asynchronous meeting. Asynchronous means that you are working at different times to categorize the brainstorming ideas. To simulate this, we are going to have you take turns with your group. One at a time, you will take turns organizing the brainstorming ideas into appropriate categories. Each person will have a minimum of 2 minutes and a maximum of 5 minutes at a time before the next person's turn. When you are done with your turn, you double-click on the "Instructions" activity on the left.

[Demonstrate how to shift out of the organizing activity.]

If you go 5 minutes, I will manually move you out of the activity. When it is your turn, I will move you into the activity for you. Are there any questions about how this will work? Again, each person will work for 2-5 minutes while the rest of the group waits. Each person then takes turns until the ideas are categorized to your liking.

****END ASYNCHRONOUS DIRECTIONS *****

## **START SYNCHRONOUS DIRECTIONS ***

You will work as a group at the same time to categorize brainstorming ideas. This means that there will be times when two people try to move the same brainstorming idea at the same time. Whoever clicks on the idea first will be the one to move the idea. Likewise, you may try to rename a bucket at the same time. Again, the first person to rename will be the one that is able to complete the renaming action.

## **END SYNCHRONOUS DIRECTIONS ***

## *** BRAINSTORMING DIRECTIONS FOR EVERYONE ***

The buckets that you and your group come up with will be evaluated by a panel of expert judges. These judges will rate the buckets according to how well they reflect the brainstorming ideas and how clearly they summarize the brainstorming ideas. To get full credit for this experiment, you need to score well. For this reason, please make sure that you take this experience seriously and work toward creating a well thought-out set of buckets.

When you are satisfied with the categorization and the names of the buckets, log out of the Thinktank session by clicking on the "logout" link on the top. Please make sure you click on the logout link so that I can know when you are done with the task.

[Demonstrate logging out of the Sample meeting.]

After logging out, there are two tasks that still need to be completed. First, there is a slip of paper by your computer. Please use this paper to flowchart the process or activities you undertook to complete this exercise.

[Show flowchart shapes on PPT]

These shapes show the basic elements of a flowchart, including start/end ovals, process blocks, and decision points. We are curious to learn more about the process you went through to categorize the brainstorming ideas. The flowchart is intended to provide a brief snapshot of the sequence of actions you undertook during this exercise. Please note, it is one page. We are not looking for extreme details about every click you made during this experiment. We are interested in knowing your train of thought and the process you took to complete this task. Are there any questions about this flowchart?

After completing the flowchart, please visit the URL on the whiteboard to complete a brief questionnaire about your experience here today. Your thoughtful and honest responses will help us shape the future directions of this technology. After completing the survey, you can leave the flowchart on the desk and leave the room. Please be quiet as others will still be working. If the outcome from the group is not satisfactory, according to the panel of experts, the group may not receive the full amount of extra credit possible. Please take this task seriously so that you can earn the full credit possible.

People will ask you what happened here, but please don't tell them anything about the technology or the task until the end of the semester. That would spoil our results with the rest of the people who are helping us learn about this technology. It would give us inaccurate results.

Does everyone understand how this works? Are there any questions on how this procedure works?

[Answer any procedural questions at this point]

The brainstorming ideas you will be organizing relate to the problems being experienced by a School of Business. The school is experiencing certain problems and is looking for solutions to remedy the situation. Previous groups, like yourself, met to generate the ideas that you will be categorizing. Here is a brief description of these problems.

Has everybody read the report? Are there any questions about the report?

Please log into the system using the information that is on the card by your computer. The username and password are case sensitive. Do NOT begin until I tell you to begin.

Has everyone logged into the system okay?

[Make sure everyone has accepted the consent and is successfully logged into ThinkTank]

****START SYNCHRONOUS DIRECTIONS *****

You may now double-click on the “Categorize” activity. Once you are in, please wait until everyone is logged into the activity. Can everyone log in okay?

[Make sure everyone is logged in.]

You may now start and continue until you are satisfied with the group’s results. Again, at that time, please log out, complete the flowchart, and the questionnaire.

****END SYNCHRONOUS DIRECTIONS *****

****START ASYNCHRONOUS DIRECTIONS *****

I will now start the first person from each group in the categorizing activity. When the first person is done, I will move the 2nd person into the activity and we will proceed like this. Again, you are free to change the activity to the instructions page by double-clicking that activity when you are done with your turn. Otherwise, I will move you out when your 5 minutes are up.

When you are satisfied with your group's results, you are free to log out of the session. At that time, please complete the flowchart and the questionnaire.

****END ASYNCHRONOUS DIRECTIONS *****

# APPENDIX F – EXPERIMENT 2 – CONVERGENCE - POST-SURVEY

1. How much exposure have you had to this type of University situation?

   1-2 times   3-5 times   5-10 times   10+ times   None

2. I have personally experienced one or more of these same problems:

   no   yes

3. How realistic are the problems of the School of Business?

   1   2   3   4   5

   very realistic   neutral   not at all realistic

4. How difficult did you find this task?

   1   2   3   4   5

   not at all difficult   neutral   very difficult

5. How engaging did you find this task?

   1   2   3   4   5

   very engaging   neutral   not at all engaging

6. The meeting methods we used today (did not meet - met) my expectations:

   1   2   3   4   5

   met   neutral   did not meet

7. Today’s meeting process was (inadequate - adequate) to meet our goals:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| inadequate | | neutral | | adequate |

8. How satisfied were you with the process we used today?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| satisfied | | neutral | | dissatisfied |

9. The outcome of today’s meeting is:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| satisfactory | | neutral | | unsatisfactory |

10. Thinking about the tools and methods we used today:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| I prefer other tools and methods | | neutral | | I prefer today's tools and methods |

11. How do you feel about the process by which you categorized solutions?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| dissatisfied | | neutral | | satisfied |

12. How do you feel about the proposed categorization?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| dissatisfied | | neutral | | satisfied |

13. Overall, how enjoyable did you find your experience?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| not at all enjoyable | | neutral | | very enjoyable |

14. How effective was your group at categorizing solutions?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| not at all effective | | neutral | | very effective |

15. How much do you feel you participated in this idea categorization session?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| not very much | | neutral | | a great deal |

16. How motivated were you to organize and categorize the brainstorming ideas well?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| very motivated | | neutral | | not at all motivated |

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