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Design and evaluation of a voting tool in a collaborative environment

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ABSTRACT

DESIGN AND EVALUATION OF A VOTING TOOL IN A COLLABORATIVE ENVIRONMENT

by
Zheng Li

This dissertation research designed, implemented, and evaluated a Web-based Dynamic Voting Tool for small group decision-making in a collaborative environment.

In this dissertation, the literature on voting tools in current GDSS research is presented. Various voting theories and methods are analyzed, and the advantages and weaknesses are compared, so as to gain a better understanding of how to apply these different voting methods to diverse decision-making situations. A brief overview of scaling theories is also given, with an emphasis on Thurstone's Law.

The basic features of some web-based voting tool implementations are reviewed along with a discussion of the pros and cons of Internet voting. A discussion of Human Dynamic Voting (HDV) follows; HDV allows multiple voting and continuous feedback in a group process. The Dynamic Voting Tool designed and developed by the author (i.e., Zheng Li) integrated multiple scaling and voting methods, and supported dynamic voting. Its features, user feedback, and future improvements are further discussed.

A controlled experiment was conducted to evaluate the effects of the Dynamic Voting Tool (along with the List Gathering Tool by Yuanqiong Wang) interacting with small group process. The design and procedures of the experiment, and the data analysis results extracted from 187 student subjects from New Jersey Institute of Technology are reported. While the System Survey yielded very positive feedback on the voting tool, the hypotheses tested by the Post-Questionnaire and expert judgments showed no major

positive significant results. This was probably due to the complexity of the task and procedures, lack of motivation of the subjects, bad timing, insufficient training, and uneven distribution of subjects, etc.

Several field studies using the Social Decision Support System (SDSS) Toolkit (List Gathering Tool + Dynamic Voting Tool) are presented. The SDSS system worked well when the subjects were motivated. The field studies show that the toolkit can be used in course evaluations, or other practical applications.

Finally, it is suggested that future research can focus on improving the voting tool with true dynamic features, exploring more issues on SDSS systems design and experimentation, and exploring the relationship of voting and GSS.

DESIGN AND EVALUATION OF A VOTING TOOL IN A COLLABORATIVE ENVIRONMENT

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This dissertation is dedicated to my beloved family

To my father and mother who hold the family together

To my brothers and sisters who always care about me and give me strength

Everything I do, I do it for you!

To my grandmother and my mother in heaven
I can always feel your blessing

To my best friend Jiuhong Ma
Your friendship is the most precious thing I ever had
I'd like to share every shred of my joy and happiness with you

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CHAPTER 1

INTRODUCTION: GDSS RESEARCH AND THE VOTING TOOL

In research on computer mediated group decision support systems, the tools and procedures used are the fundamental cause of the expected changes in process and outcome (Fjermestad & Hiltz, 1998). According to Fjermestad and Hiltz's paper (1998), of the approximately 200 different controlled experiments that had been published in 230 articles in referred journals or major conference proceedings by mid-1998, which examined processes and outcomes in computer-supported group decision making, the most frequently used task support tool is Brainstorming (44 studies) for idea generation, followed by voting (35) or some other form of ranking or preference rating (20) for support of preference or decision making tasks. In another study that summarized the case and field studies of group support systems, Fjermestad and Hiltz (2000) reported that, of the 30 case and field studies from 47 published papers spanning two decades of group support systems (GSS) research, the most frequently used task support tool is Brainstorming (13 studies) for idea generation, followed by voting (9), topic commenter (8), ranking (4) and issue organizer (4). Yet they state, "Most experiments seem to (falsely) assume that all GSS's are a standard 'package' that will have the same effect." "It appears that there has been a tendency for the first tool tried to be accepted uncritically by subsequent system designers." Clearly, some technology factors have been overlooked in the past GDSS study.

In this dissertation, the author is concerned with using appropriate decision models for facilitating a full understanding by the group of individual preferences among its members. Also it is wished that these models can aid in determining the degree of understanding and agreement at any time in the group process. As a result of being able to accomplish this, it is hypothesized that the group will be more likely to develop a group view of complex problems that is more consistent with the views of the members at the end of the process. Furthermore, consensus of the group will be either enhanced, or the lack of it will be better understood by the individual members in the group. Voting tools are one such modeling approach that this effort will be focusing on.

Computerized voting, or electronic voting, has recently gained a lot of attention due to the recount incident in the 2000 U. S. Presidential election. It has become a very convenient way and almost a fashion now to ask people to vote on certain popular events in the news media through their web sites. However, the attention paid to computerized voting seems to be concentrated on large-scale elections/events thus far. Research on voting in GSS to support small groups in decision-making is sparse. Researchers at NJIT pointed out recently (Cheng, Li, and Van De Walle, 2001):

> It is undeniable that voting has not received enough emphasis in GSS research. While most GSS have incorporated voting tools, e.g., EIES 2 (Dufner et al., 1995), GroupSystems (Nunamaker et al., 1991), SAMM (Watson et al., 1988), and TERMS (Turoff et al., 1993), researchers seldom report how voting tools are used in their studies. In addition, published research rarely mentioned what kind of voting methods (for example, plurality method, majority rule, or approval voting, etc.) was implemented in the systems.

Instinctively, people will seek to vote on any issues before they make the final decision during decision-making. Why? Kraemer and King (1988) suggest that voting systems have a pronounced effect on group decision making, that is, voting systems allow groups to identify variance in issues rapidly and anonymous voting can reduce bias of dominant individuals. They also suggest that voting tools should be used to discover the lack of consensus and enable the group to explore the issue at a deeper level, not to signify the end of the decision process.

Nunamaker and his colleagues (Nunamaker, Briggs, and Mittleman, 1994) have reported lessons learned with the use of GroupSystems. Their conclusion on electronic voting is similar to the suggestions of Kraemer and King (1988). That is, the use of voting tools can uncover patterns of consensus and encourage group thinking; anonymous voting can bring up issues that were buried during normal conversation; electronic voting can facilitate decisions that are too painful to make using traditional methods. They observed that groups using structured voting to focus discussion have higher decision quality than groups using traditional voting methods. They also warn that all criteria should be clearly established and defined before voting. However, their report does not illustrate the relationship among voting tools, voting procedures, and decision outcomes. By emphasizing setting up criteria before voting, they also imply that voting is only a one-time ending process. However, the author's vision is that voting can be used to explore the issues and help establish the criteria, and enable the understanding between group members.

Nevertheless, currently voting is very often viewed and been used as the concluding step in the group process and not as a potential instrument for measuring the process of the group in the inspection of their problem, promoting understandings between group members to eliminate ambiguities, fostering exploration of the solutions, and guiding the group process. Given the problems of classical one-time voting, the author proposed to improve the group process by providing a feedback mechanism for group voting, that is, using a Human Dynamic Voting (HDV) model to improve the group performance. Human Dynamic Voting is the voting process that incorporates the use of scaling methods, voting schemes (i.e., voting methods), and dynamic voting procedures in a freely interacting group. "Dynamic" means that the voting is not done just once per person, but can be allowed to carry out freely for many times during a certain time slot, until certain preset criteria are met, such as deadlines, times of repeated votes, or number of total votes. The development of computer technology and the fast growth of the World Wide Web has provided an opportunity to construct the voting tools on the Web, so that either large groups or small groups can take advantage of the technology – Web-based dynamic voting tool.

Scaling is the science of determining measuring instruments for human judgment (McIver, 1981). Clearly, one needs to make use of appropriate scaling methods to aid in improving the accuracy of subjective estimation and voting procedures (Turoff & Hiltz, 1997). Nobody would deny the fact that all science advances by the improvement of its measurement instruments. Torgerson (1958) pointed out that scaling, as a science of measuring human judgment, is as fundamental as collecting data on well-developed natural sciences. Scaling becomes a critical component of the dynamic voting process. The use of scaling provides understanding to the voters of their views as a group insider to allow them to improve the results. And the objectives are to increase the individual consistency and the clarity of the group position. In this dissertation, the author will carefully justify any scaling method before employing it into the voting procedures.

CHAPTER 2

VOTING AND SCALING THEORIES

Consider groups in a situation of conflict and cooperation in a group decision-making setting. Individuals within the group form coalitions and use their power and influence to extract results. In this chapter, it is assumed that a group is trying to make decisions on democratic grounds, where each individual is treated equally. Each member of the group has his or her preferences or opinions. The author is interested in developing toolkits for groups to establish fair and uniform procedures to combine the individual opinions together to reach group consensus, or expose disagreement between group members to reach better understanding and consistency. Obviously one of the most common tools the group needs is a list-gathering tool for a group to sufficiently express and collect its different opinions on a topic. Another useful tool is a voting tool, which can let the individuals in a group vote on its choices according to certain rules and procedures. The voting tool is what this dissertation is focusing on.

2.1 Voting Theories

When talking about voting, one may think it's such a simple thing: as people saw in elections, each voter voted for his or her first choice, and the winner is then declared as the one who gets the most votes. If no one gets a majority, there are sometimes runoff procedures between the top two vote-getters. Unfortunately, the result of such an election is often not a very popular winner. On the other hand, in many situations, it is more useful to produce a ranking of all the candidates than it is to just produce a winner. This is the case, for example, if the candidates are candidates for a job and the rankings are provided by different judges, for one shall want to make an offer to a second choice if the top candidate does not accept the job, an offer to a third if the second candidate does not accept, and so on. What rules and procedures should be followed to choose the ranking of candidates? In this section, voting methods will be discussed for determining this winner, or more generally, for obtaining a consensus ranking of all the candidates which somehow represents the group's opinion. Meanwhile, the potential problems and limitations of these alternative voting methods will be highlighted.

Most voting systems are based on the concept of ranking candidates in order of preference, and then using various methods to tabulate the preferences, which make different tradeoffs between immunity to strategy, trueness of compromise, and other criteria that may be somewhat subjective in nature. Unfortunately, many claim that there cannot be a "perfect" method due to Arrow's Impossibility Theorem (Arrow, 1952).

Nonetheless, many mathematicians and electoral reformers have struggled to come up with voting systems that are more acceptable than the status quo, and have done so with great theoretical success. Currently, the most popular among reformers, is Majority Preference Voting (or Instant Runoff, also known as Hare's methods) (Lanphier, 2000). Compared with the standard vote-for-only-one methods, this method successively eliminates the least popular candidate from the election until a winner remains, using the ranked ballot to redistribute the votes of the eliminated candidate. There are many other methods similar to this one, such as Approval Voting – Voters are allowed to vote for all candidates they approve. The candidate with the highest number of "yes" votes wins. The Netscape Open Directory Project now has a relatively complete list of alternate voting systems. (Please refer to the URL below for the Web site:

http://dmoz.org/Society/Politics/Campaigns_and_Elections/Voting_Systems/, Retrieved 06/2001).

A collection of voting methods is listed below starting with the definitions, standard and criteria, and then the details of several alternative voting methods will be discussed further.

2.1.1 Definitions

One needs to understand the basic concepts of voting and their definitions before discussing the voting methods. Voting related terms and their brief definitions are listed in Table 2.1 (Cretney, 1998):

Table 2.1 Voting Terms and Definitions

Term	Definition
bullet voting	Reducing the number of alternatives you express a preference for, or give some rating to. This is a type of burying strategy.
Burying	Insincerely ranking an alternative lower in the hope of defeating it.
circular preferences	Pair-wise majorities in the expressed or actual opinions of voters that are inconsistent.
Clones	See twins.
compromising	Insincerely ranking an alternative higher in the hope of getting it elected.
Condorcet winner	An alternative that pair-wise beats every other alternative. "Condorcet" is a proper noun, and should be capitalized.
crowding	The effect where more candidates representing an ideology effects the outcome, but does not for the given ideology.
cycle	A path from an alternative to itself. For example A > B, B > C, C > A
eliminate	Remove an alternative from consideration for winning and having further effect on the process being used.
fratricide	When the pair-wise victories between members of a twin set result in an alternative from outside the set being elected. This is a type of vote splitting.
insincere	A vote that does not correspond to the voters' true preference. This correspondence is defined by the method.
lesser of two evils	This is another way of presenting the problem created by the "compromising" strategy.
majority	More than half.

Table 2.1 Voting Terms and Definitions (Continued)

<table>
<tr><th>Term</th><th>Definition</th></tr>
<tr><td>monotonicity</td><td>The property of a method where an alternative can never be made to succeed by being ranked lower on some ballots. Doing this is using the “push-over” strategy.</td></tr>
<tr><td>non-monotonicity</td><td>The property of a method that does not have monotonicity.</td></tr>
<tr><td>pair-wise matrix</td><td>A table showing for every pair of alternatives, how many voted the alternative corresponding to the row over the alternative corresponding to the column.
<table>
<tr><td></td><td>A</td><td>B</td><td>C</td></tr>
<tr><td>A</td><td>X</td><td>7</td><td>8</td></tr>
<tr><td>B</td><td>4</td><td>X</td><td>9</td></tr>
<tr><td>C</td><td>5</td><td>2</td><td>X</td></tr>
</table>
This shows that A has a pair-wise victory over B of 7 to 4.</td></tr>
<tr><td>pair-wise victory</td><td>X has a pair-wise victory over Y if more voters rank X over Y than Y over X.</td></tr>
<tr><td>path</td><td>A sequence of pair-wise victories such that the winner of each victory after the first is the same alternative as the loser in the previous. E.g.: A>B, B>C, C>D.</td></tr>
<tr><td>proportional representation</td><td>Parties having representation in a legislature in proportion to the number of their voter's in the election.</td></tr>
<tr><td>push-over</td><td>The strategy of ranking a weak alternative higher than one’s preferred alternative, which may be useful in a method that violates monotonicity.</td></tr>
<tr><td>rank ballot</td><td>A ballot that allows the voter to order the candidates with regard to preference, but does not allow the voter to show extent of preference.</td></tr>
<tr><td>ratings ballot</td><td>A ballot that allows the voter to rate the extent of their preference for each candidate.</td></tr>
<tr><td>sincere</td><td>A vote that corresponds to the voter’s true preference. This correspondence is defined by the method.</td></tr>
<tr><td>Smith set</td><td>The smallest non-empty set of alternatives such that every alternative in the set pair-wise beats every alternative outside the set.</td></tr>
<tr><td>sophisticated vote</td><td>An insincere vote that is more likely to lead to a favorable outcome based on the electoral method and the information known to the voter.</td></tr>
<tr><td>strategic nominating</td><td>Using the nominating process to gain advantage. In particular, using vote-splitting, teaming, and crowding strategies.</td></tr>
<tr><td>strategic vote</td><td>An insincere vote that the voter thinks is more likely to lead to a favorable outcome. In particular, using compromising, burying, and push-over strategies.</td></tr>
<tr><td>truncate</td><td>To insincerely leave unranked alternatives who will therefore be counted as equal and lower than all ranked alternatives. This is one type of burying strategy.</td></tr>
<tr><td>twins</td><td>A set of alternatives {X(1), X(2), …, X(m)} are twins provided that for every alternative Z, where Z is not one of {X(1), …, X(m)}, the following is true: Every ballot that ranks Z higher than one of {X(1), …, X(m)} ranks Z higher than all of them. Every ballot that ranks Z lower than one of them, ranks Z lower than all of them. Every ballot that ranks Z equal to one of them ranks Z equal to all of them. As well, there must be at least one alternative outside the set of twins. Notes: Although we usually think of twins as coming in two's, as far as this definition goes they can come in any number.</td></tr>
<tr><td>vote-splitting</td><td>When multiple similar alternatives are defeated because their support is not concentrated on one of them.</td></tr>
</table>

2.1.2 Standards and Criteria

One needs to set up some common standards and criteria to start with when discussing voting theories and methods.

Standards A standard is a basis on which election methods may be judged. There will usually be lively debate about whether a standard is useful, which methods meet the standard, and to what extent. Table 2.2 lists a few that are sometimes mentioned (Cretney, 1998).

Table 2.2 Voting Standards

Name	Definition	Purpose
Strategy-free	It should never be useful to a voter to rank or rate candidates by other than the voter's true preference.	To allow the voter to freely express an honest preference.
Simplicity of Explanation	A method should be as simple to explain as possible.	-
Simplicity of Use	A method should be as simple for the voter to use as possible.	-
Truncation Resistance	A method should be as unaffected by strategic truncation as possible.	Supporters contend that the most likely type of insincere vote is truncation. Therefore it makes sense to concentrate on preventing truncation.

Criterion A basis on which an election method can be judged. Criteria are phrased in such a way that all methods will either pass or fail the criterion, and it can be proved which. The most common criteria, their definitions, and the voting methods that pass or fail the criterion are listed in the Table 2.3 below (Cretney, 1998).

Table 2.3 Voting Criteria

Name	Application	Definition	Pass	Fail
Consistency Criterion		For any way the ballots are divided into two groups, if X is the winner for both groups independently, X must also be the winner if the ballots are not separated.	Approval, Approval /Disapproval, Average Rating, Borda	Median Rating, Condorcet-Elimination, Tideman, Schulze, Bucklin, IRV, Dodgson, Condorcet, Smith/Condorcet, Nanson, Young, Coombs, Black
General Independence from Twins Criterion: GITC		If there are alternatives X1, X2 ... Xn that are twins, and if all of these twins except one are eliminated from every ballot, then, if one of these twins won for the old ballots, the remaining twin must win for the new. If a different alternative won before, it must still win.	Approval, Approval /Disapproval, Average Rating, Median Rating, Condorcet-Elimination, Tideman, Schulze, IRV	Dodgson, Minmax, Smith/Minmax, Bucklin, Borda, Young, Coombs, Black, Nanson
Monotonicity Criterion		If an alternative X loses, and the ballots are changed only by placing X in lower positions, without changing the relative position of other candidates, then X must still lose.	Approval, Approval /Disapproval, Average Rating, Median Rating, Tideman, Schulze, Minmax, Smith//Minmax, Bucklin, Borda, Young, Black	Minmax-Elimination, IRV, Nanson, Coombs, Dodgson
Reversal Symmetry Criterion		If alternative X wins, and all rankings on all ballots are reversed, then X must lose.	Approval, Approval /Disapproval, Average Rating, Median Rating, Tideman, Schulze, Borda, Black	Minmax-Elimination, IRV, Minmax, Smith//Minmax, Nanson, Young, Coombs, Dodgson, Bucklin

Table 2.3 Voting Criteria (Continued)

Name	Application	Definition	Pass	Fail
Secret Preferences Criterion: SPC		If alternative X wins, and some of the ballots are modified in their rankings below X, X must still win.	IRV	Average Rating, Median Rating, Minmax-Elimination, Tideman, Schulze, IRV, Dodgson, Minmax, Smith//Minmax, Bucklin,Borda, Nanson, Young,Coombs, Black
Smith Criterion	Ranked ballots	The winner must be a member of the Smith set.	Minmax-Elimination, Tideman, Schulze, Smith//Minmax, Nanson	IRV, Minmax, Bucklin, Borda, Dodgson, Young, Black, Coombs
Condorcet Criterion	Ranked ballots	If an alternative pair-wise beats every other alternative, this alternative must win the election.	Minmax-Elimination, Tideman, Schulze, Dodgson, Minmax, Smith//Minmax, Nanson, Young, Black	IRV, Bucklin, Borda, Coombs
Condorcet Loser Criterion	Ranked ballots	If an alternative pair-wise loses to every other alternative, this alternative must lose the election.	Minmax-Elimination, Tideman, Schulze, IRV, Smith//Minmax, Nanson, Coombs, Black	Minmax, Bucklin, Borda, Dodgson, Young
Local Independence from Irrelevant Alternatives Criterion (LIIAC)	Ranked ballots	If an election produces winner X, and a new alternative is added (Y), and Y is not in the Smith set, the new election must also produce winner X.	Minmax-Elimination, Tideman, Schulze, Smith//Minmax,	IRV, Minmax, Bucklin, Borda, Dodgson, Young, Nanson, Coombs
Mutual Majority Criterion	Ranked ballots	If there is a majority of voters for which it is true that they all rank a set of candidates above all others, then one of these candidates must win.	Minmax-Elimination, Tideman, Schulze, Bucklin, IRV, Smith//Minmax, Nanson, Coombs	Minmax, Borda, Dodgson, Young, Black

Table 2.3 Voting Criteria (Continued)

Name	Application	Definition	Pass	Fail
Pareto		If an alternative (X) is ranked or rated lower than another alternative (Y) on every ballot, X must lose.	Approval, Approval /Disapproval, Average Rating, Median Rating, Minmax-Elimination, Tideman, Schulze, Bucklin,IRV, Dodgson, Minmax, Smith//Minmax, Borda, Nanson, Young, Coombs, Black	None
Majority Criterion	Ranked ballots	If an alternative is ranked first on a majority of ballots, that alternative must win.	Minmax-Elimination, Tideman, Schulze, Bucklin, IRV, Dodgson, Minmax, Smith//Minmax, Nanson, Young, Coombs, Black	Borda

2.1.3 Comparing Alternative Voting Methods

As discussed above, different voting methods are based on different voting criteria, and each has its unique advantages and problems. The simplest voting method is known as Plurality Voting (PV) – Each voter votes for only one alternative, and the alternative with the most votes wins. Some frequently used voting methods such as PV will be discussed below with more details, and their problems in use will be highlighted. The alternatives to Plurality Voting to be compared are: the Condorcet's Method, the Hare System of Single Transferable Vote (STV), the Borda Count, Cumulative Voting, and Approval Voting (Brams, et al., 1991).

Suppose there are a set of individuals, to be called voters; and a set of objects, alternatives, factors, events, candidates, etc., among which the individuals make certain judgments, and to be called items or alternatives, the Hare System and the Borda Count allow voters to rank the items, and Cumulative Voting allows voters to allocate a fixed number of votes among items. These systems are designed to ensure proportional representation of different subgroups in the group voting process. Approval Voting is a non-ranked voting system that tends to help items with majority preferences. All these voting systems are vulnerable to strategic manipulation, with the Borda Count being the most manipulable.

2.1.3.l Plurality Voting: With and Without a Runoff. The voting procedures used for a group of voting items determine to a crucial degree whether the voting is considered fair and its outcomes validate/legitimate. The term "procedures" mean the rules that govern how votes in a voting system are aggregated, and how a winner or winners are determined. The term "voting system" refers to the computerized voting procedures that interacted in small or large group decision-making settings. Here the term "items" is used to refer to the alternatives (two or more) that to be voted on.

The two best-known and most commonly used voting procedures restrict voters to voting for only one item, regardless of how many alternative items. They are Plurality Voting (the item with the most votes wins) and Plurality Voting With a Runoff (the two items with the most votes are paired against each other in a second, or runoff, voting; the item with the most votes in the runoff voting wins). Runoff Voting is held only if the winner in the first round does not receive a majority – or some other designated percentage, such as 40 percent – of the votes.

In a situation of conflict-solving, Runoff Plurality Voting can prevent an item which may be preferred by, say, 35 percent of the voters, from defeating items preferred by the majority which might split the remaining 65 percent of the vote. By pairing one of the majority items against the minority preferred item, Runoff Voting helps to ensure that one of the majority preferred items gets selected, provided that most of the supporters of the defeated majority preferred item vote for the majority item in the runoff.

The procedures of Plurality Voting, with or without a runoff, are vulnerable to strategic voting, whereby rational voters vote insincerely (not in accordance with their preferences) to try to obtain a preferred outcome. Take an example of a political election. If two majority candidates are pitted against a minority candidate, under Plurality Voting (without a runoff), a voter might vote insincerely for the majority candidate who seems to have the better chance of winning to try to prevent the minority candidate from winning, even though this voter might prefer the other majority candidate. On the other hand, if there were a runoff voting, supporters of either of the majority candidates would presumably vote sincerely in the first election, because at least one of the majority candidates would be selected in the first round, and defeat the minority candidate in the runoff if that candidate were also in the runoff.

The words "minority" and "majority" have been used inaccurately here. Subsequent analysis will be more precise about strategic calculations and their effects on outcomes. The purpose in analyzing better and worse strategies under alternative procedures is not only to illuminate their strategic properties, but also to illustrate paradoxes that can arise under them.

2.1.3.2 Condorcet's Method. Condorcet's Method (Condorcet, 1785) is a pair-wise method. It is named after the 18th century election theorist who invented it. Condorcet's Method lets one rank the items in the order of preference in which one would see them voted. The votes are tallied by computing the results of separate pair-wise voting between all of the alternative items, and the one that wins a majority in all of the pair-wise voting is the winner.

Suppose for three items A, B, and C, a voting result is as follows: Item A on one extreme who pulls 40% of the vote, item B in the middle who only pulls 20% of the vote, and item C on the other extreme who pulls 40% of the vote. Assumes item B is indeed the second choice for the group who preferred A and the group who preferred C, which will be the Condorcet's winner?

40%: A > B > C
20%: B > A > C
40%: C > B > A

The best result of this is that item B will get elected as a compromise. Why? Here is how it works: in a pair-wise comparison between A and B, B wins with 60% of the vote, and in a pair-wise comparison between B and C, B also wins with 60% of the vote. Since B wins all pair-wise elections, B wins.

Though not as popular as Plurality Runoff, Condorcet's Method is debatably the best of these methods at freeing voters from strategic concerns. Condorcet's method lets voters mark their sincere wishes for which item they would prefer, without having to consider strategy (E.g., "I'd vote for item B, but I'm afraid of wasting my vote."). It is really just a logical extension of majority rule when more than two choices are involved.

2.1.3.3 The Hare System of Single Transferable Vote (STV). First proposed by Thomas Hare in England and Carl George Andrae in Denmark in the 1850s, STV has been adopted in political elections throughout the world. It is also called the "alternative vote." Although STV is known to violate a number of properties of voting systems discussed in the literature on social choice theory (Kelly, 1987), it has a number of strengths as a system of proportional representation. In particular, minorities' opinion could be reflected in proportion of their voting. Minorities can get a number of preferred items, roughly proportional to their numbers in the electorate, elected if they rank these items at the tops of their lists. Also, if a person's vote does not help elect his/her first choice, it can still be counted toward lower choices.

To describe how STV works and also illustrate two properties that it fails to satisfy, consider the following examples (Brams, 1982; Brams and Fishburn, 1984). The first shows that STV is vulnerable to "truncation of preferences" when two out of four items are to be selected. The second shows that it is also vulnerable to "non-monotonicity" when there is one item to be selected and there is no transfer of so-called surplus votes.

Example 1. Assume that there are three classes of voters who rank the set of four items {*x, a, b, c*} as follows:

I. 6 voters: *x a b c*
II. 6 voters: *x b c* a
III. 5 voters: *x c a b*

Assume also that two of the four items are to be selected, and an item must receive a quota of six votes to be selected on any round. A "quota" is defined as (n/(m+1)) + 1, where n is the number of voters and m is the number of items to be selected. It is standard procedure to drop any fraction that results from the calculation of the quota, so the quota actually used is q = Integer ((n/(m+1)) + 1), the integer part of the number in brackets. The integer quota is the smallest number that makes it impossible to elect more than m items by first-place votes on the first round. Since q = 6 and there are 17 voters in this example, at most two items can attain the quota on the first round (18 voters would be required for three candidates to get six first-place votes each). In fact, what happens is as follows:

1st round: *x* receives 17 out of 17 first-place votes and is elected.

2nd round: There is a "surplus" of 11 votes (above q = 6) that are transferred in the proportions 6:6:5 to the second choices (*a*, *b*, and *c*, respectively) of the three classes of voters. Since these transfers do not result in at least q = 6 for any of the remaining items (3.9, 3.9, and 3.2 for *a*, *b*, and *c*, respectively), the item with the fewest (transferred) votes (i.e., *c*) is eliminated under the rules of STV. The supporters of *c* (class III) transfer their 3.2 votes to their next-highest choice (i.e., *a*), giving a more than a quota of 7.1. Thus, *a* is the second alternative selected. Hence, the set of winners is {*x*, *a*}.

Now assume that two of the six class II voters indicate *x* is their first choice, but they do not indicate a second or third choice. That is:

I.	6 voters: *x a b c*
II.	4 voters: *x b c a*
III.	2 voters: *x*
IV.	5 voters: *x c a b*

The new results are:

1st round: Same as earlier.

2nd round: There is a surplus of 11 votes (above q = 6) that are transferred in the proportions 6:4:2:5 to the second choices, if any (*a*, *b*, no second choice, and *c*, respectively) of the voters. (The two class II voters do not have their votes transferred to any of the remaining items because they indicated no second choice.) Since these transfers do not result in at least q = 6 for any of the remaining items (3.9, 2.6, and 3.2 for *a*, *b*, and *c*, respectively), the item with the fewest transferred votes (i.e., *b*) is eliminated. The supporters of *b* (four voters in class II) transfer their 2.6 votes to their next-highest choice (i.e., *c*), giving *c* 5.8, less than the quota of six. Because *a* has fewer transferred votes (3.9), *a* is eliminated, and *c* is the second item selected. Hence, the set of winners is {*x*, *c*}.

Observe that the two class II voters who ranked only *x* first induced a better social choice for themselves by truncating their ballot ranking of alternatives. Thus, it may be advantageous not to rank all alternatives in order of preference on one's ballot, contrary to a claim made by a mathematical society that "there is no tactical advantage to be gained by marking few alternatives" (Brams, 1982). Put another way, one may do better under the STV preferential system by not expressing preferences – at least beyond first choices.

The reason for this in the example is that the two class II voters, by not ranking *b*-*c*-*a* after *x*, prevent *b*'s being paired against *a* (their last choice) on the second round, wherein *a* beats *b*. Instead, *c* (their next-last choice) is paired against *a* and beats *a*, which is better for the class II voters.

In case someone think that an advantage gained by truncation requires the allocation of surplus votes, an example is given next in which only one item is to be selected, so the voting procedure progressively eliminates alternatives until one remaining item has a simple majority. This example illustrates a new and potentially more serious problem with STV than its manipulability due to preference truncation.

Example 2. Assume that there are four items, with 21 voters in the following four ranking groups:

I.	7 voters:	*a b c d*
II.	6 voters:	*b a c d*
III.	5 voters:	*c b a d*
IV.	3 voters:	*d c b a*

Because no item has a simple majority of q = 11 first-place votes, the lowest first-choice candidate, *d*, is eliminated on the first round, and class IV's three second-place votes go to *c*, giving *c* eight votes. Because none of the remaining items has a majority at this point, *b*, with the new lowest total of 6 votes, is eliminated next, and *b*'s second-place votes go to *a*, who is elected with a total of 13 votes.

Next assume that the three class IV voters indicate only *d* as their first choice. Then *d* is still eliminated on the first round, but since the class IV voters did not indicate a second choice, no votes are transferred. Now, however, *c* is the new lowest item, with 5 votes; *c*'s elimination results in the transfer of its votes to *b*, which is elected with 11 votes. Because the class IV voters prefer *b* to *a*, it is in their interest not to rank items below *d* to induce a better outcome for themselves, again illustrating the truncation problem.

It is true that under STV a first choice can never be hurt by ranking a second choice, a second choice by ranking a third choice, etc., because the higher choices are eliminated before the lower choices can affect them. However, lower choices can affect the order of elimination, and hence the transfer of votes. Consequently, a higher choice (e.g., second) can influence whether a lower choice (e.g., third or fourth) is elected.

These examples show that to rank all items for which one has preferences is not always rational under STV, despite the fact that it is a preferential voting procedure. On the other hand, it is not the case that voters would routinely make the strategic calculations implicit in these examples. These calculations are not only complex but also might be neutralized by counter-strategic calculations of other voters.

Example 2 illustrates another paradoxical aspect of STV: raising an item in one's preference order can actually hurt that item. This is referred to as non-monotonicity (Smith, 1973; Doron and Kronick, 1977; Fishburn, 1982; Bolger, 1985). Thus, if the three class IV voters raise "*a*" from fourth to first place in their rankings – without changing the ordering of the other three candidates – "*b*" is elected rather than "*a*". This is indeed perverse: "*a*" loses when it moves up in the rankings of some voters and thereby receives more first-place votes. Equally strange, items may be helped under STV if voters do not show up to vote for them at all, which has been called the "no-show paradox" (Fishburn and Brams, 1983; Moulin, 1986; Ray, 1986; Holzman, 1987).

The fact that more first-place votes or even no votes can hurt rather than help an item violates what is arguably a fundamental democratic ethic. Single Transferable Vote (STV) also does not guarantee the election of Condorcet candidates – those who can defeat all other candidates in separate pair-wise contests. Thus in example 2, "*b*" is the Condorcet candidate: "*b*" is preferred to "*a*" by 14 voters (class II, III, and IV voters), whereas "*a*" is preferred to "*b*" by only seven voters (class I); similarly, "*b*" is preferred to "*c*", 13-8, and to "*d*", 18-3. However, "*a*" is elected under STV.

2.1.3.4 The Borda Count. Under a system proposed over two hundred years ago (Borda, 1781), points are assigned to items so that the lowest ranked item of each voter receives zero points, the next-lowest one point, and so on up to the highest ranked item, who receives m-1 points if there are m items. Points for each item are summed across all voters, and the item with the most points wins. It has been known that the Borda Count and similar scoring methods are not used to elect candidates in any public elections, but they are used by many private organizations (Young, 1975).

Like STV, the Borda Count need not elect the Condorcet candidate. This is illustrated by the case of three voters with preference order *a-b-c* and two voters with preference order *b-c-a*. Under the Borda Count, "*a*" receives six points, "*b*" seven points, and "*c*" two points, making "*b*" the Borda winner; yet "*a*" is the Condorcet candidate.

On the other hand, the Borda Count would elect the Condorcet candidate (e.g., *b*) in Example 2 of the preceding section. This is because "*b*" occupies the highest position on the average in the rankings of the four sets of voters. Specifically, "*b*" ranks second in the preference order of 18 voters and third in the order of three voters, giving "*b*" an average ranking of 2.14, which is higher than *a*'s average ranking of 2.19 as well as the rankings of "*c*" and "*d*". Having the highest average position is indicative of being broadly acceptable to voters, unlike Condorcet candidate "*a*" in the preceding section, which is the last choice of two of the five voters.

Unfortunately, the Borda Count is readily subject to manipulation. Consider again the example in which three voters have preference order *a-b-c* and two voters have order *b-c-a*. Recognizing the vulnerability of their first choice, *a*, under the Borda Count, the three *a-b-c* votes might insincerely rank the candidates *a-c-b*, maximizing the difference between their first choice *a* and *a*'s closest competitor *b*. This would make *a* the winner.

In general, voters can gain under the Borda Count by ranking the most serious rival of their favorite item last in order to lower its point total (Ludwin, 1978). This strategy is relatively easy to effectuate, unlike a manipulative strategy under STV that requires estimating who is likely to be eliminated, and in what order, so as to be able to exploit STV's dependence on sequential eliminations and transfers.

The vulnerability of the Borda Count to manipulation led Borda to exclaim, "My scheme is intended only for honest men" (Black, 1958). Nurmi (1984) has shown that the Borda Count, like STV, is also vulnerable to preference truncation, giving voters an incentive not to rank all candidates in certain situations. However, Chamberlin and Courant (1983) contend that the Borda Count would give effective voice to different interests in a representative assembly, if not always ensure their proportional representation.

Another type of paradox that afflicts the Borda Count and related point-assignment systems involves manipulability by changing the agenda. For example, the introduction of a new item, which cannot win – and, consequently, would appear irrelevant – can completely reverse the point-total order of the old items, even though there are no changes in the voter's rankings of these items (Fishburn, 1974). Thus, in the example below, the last-place item *a* (with six votes) among three items jumps to the first-place (with 13 votes) when "irrelevant" item *x* is introduced, illustrating the extreme sensitivity of the Borda Count to apparently irrelevant alternatives.

Without item x: {a, b, c}		With item x: {a, b, c, x}	
3: c b a 2: b a c 2: a c b	c = 8 b = 7 a = 6	3: c b a x 2: b a x c 2: a x c b	a = 13 b = 12 c = 11 x = 6

Clearly, it would be in the interest of *a*'s supporters to encourage *x* to enter simply to reverse the order of Borda count result.

2.1.3.5 Cumulative Voting. Cumulative Voting is a voting system in which each voter is given a fixed number of votes to distribute among one or more alternatives. This allows voters to express their intensities of preference rather than simply to rank items, as under STV and the Borda Count. It is a system of proportional representation in which minorities can ensure their approximate proportional representation by concentrating their votes on a subset of items commensurate with their size in the voters.

To illustrate this system and the calculation of optimal strategies under it, assume that there is a single minority position favored by one-third of the voters and a majority position favored by the remaining two-thirds. Assume further that there are 300 voters, who are required to select six items, and that the six items with the most votes win.

If each voter has six votes to cast for as many as six items, and if each of the 100 voters in the minority casts three votes each for only two items, these voters can ensure the election of these two items no matter what the 200 voters in the majority do. For each of these two minority items will get a total of 300 (100 x 3) votes, whereas the two-thirds majority, with a total of 1,200 (200 x 6) votes to allocate, can at best match this sum for its four alternatives (1,200/4 = 300).

If the two-thirds majority instructs its supporters to distribute their votes equally among five alternatives (1,200/5 = 240), it will not match the vote totals of the two minority alternatives (300) but can still ensure the election of four (of its five) alternatives – and possibly get its fifth item elected if the minority (mistakenly) puts up three alternatives and instructs its supporters to distribute their votes equally among the three (giving each 600/3 = 200 votes).

Against these strategies of either the majority (support five items) or the minority (support two items), it is easy to show that neither side can improve its position. To elect five (instead of four) items with 301 votes each, the majority would need 1,505 instead of 1,200 votes, holding constant the 600 votes of the minority; similarly, for the minority to elect three (instead of two) items with 241 votes each, it would need 723 instead of 600 votes, holding constant the 1,200 votes of the majority.

It is evident that the optimal strategy for the leaders of both the majority and minority is to instruct their members to allocate their votes as equally as possible among a certain number of alternatives. The number of alternatives they should support for the elected body should be proportionally about equal to the number of their supporters in the electorate (if known).

Any deviation from this strategy – for example, by putting up a full slate of alternatives and not instructing supporters to vote for only some on this slate – offers the other side the opportunity to capture more than its proportional "share" of the seats. Clearly, good planning and disciplined supporters are required to be effective under this system.

2.1.3.6 Approval Voting. As indicated previously, a minority alternative, with support from a relatively small percentage of the voters, could either win a plurality election outright or qualify for a runoff. In the example given previously, the runoff would deny the election of the minority item. On the other hand, a potential defect of runoffs is that a Condorcet candidate may not even make the runoff.

For example, if there are strong minority alternatives on both the left and the right, a moderate alternative in the middle may receive the smallest percentage of the vote. Yet this item may be in fact be able to defeat each of the minority items in separate pair-wise contests. Despite being the Condorcet candidate, however, its election would be obviated by Plurality Voting, with or without a runoff.

Approval Voting, proposed independently by several analysts in the 1970s (Brams and Fishburn, 1983), is a voting procedure that is designed in part to prevent the election of minority items in multi-item contests (i.e., those with three or more alternative items). Under Approval Voting, voters can vote for, or approve of, as many items as they wish. Each item approved of receives one vote, and the item with the most votes wins.

Advantages of Approval Voting include the following:

- *It gives voters more flexible options.* Voters can do everything they can under the plurality system – vote for a single favorite – but if they have no strong preference for one item, they can express this by voting for all items they find acceptable. For instance, if a voter's most preferred item has little chance of winning, that voter could vote for both a first choice and a more viable item without worrying about wasting his/her vote on the less popular one.

- *It would increase voter turnout.* By being better able to express their preferences, voters would more likely go to the vote in the first place. Voters, who think they might be wasting their votes, or who cannot decide which of several alternatives best represents their views, would not have to despair about making a choice. By not being forced to make a single choice, they would feel that the voting system allows them to be more honest, which would presumably make voting more meaningful.
- *It would help elect the strongest item.* It is often the case in voting that the item supported by the largest minority often wins, or at least makes the runoff. Under Approval Voting, by contrast, it would be the item with the greatest overall support would usually win.
- *It would give minority item their proper due.* Minority items would not suffer under Approval Voting – their supporters would not be torn away simply because there was another item which, though less appealing to them, was generally considered a stronger contender. Because Approval Voting would allow these supporters to vote for both items, they would not be tempted to desert the one who is weak in the vote, as under Plurality Voting. Hence, minority items would receive their true level of support under approval voting, even if they could not win.
- *It is eminently practicable.* Approval Voting can readily be implemented on existing voting systems, and it is simple for voters to understand.

Although Approval Voting encourages sincere voting, it does not eliminate strategic calculations on the whole. Because approval of a less-preferred item could hurt a more-preferred approved item, the voter is still faced with the decision of where to draw the line between acceptable and non-acceptable items. A rational voter will vote for a second choice if his/her first choice appears to be a risk, but the voter's calculus and its effects on outcomes is not yet well understood for either Approval Voting or the other procedures discussed herein (Nurmi, 1987; Merrill, 1988).

2.1.3.7 Summary: Limitations of the Alternative Voting Method. There is no perfect voting procedure. But some procedures are clearly superior to others with respect to satisfying certain criteria. Among non-preferential voting systems, Approval Voting distinguishes itself as more sincere and more likely to select Condorcet candidates than other systems, including Plurality Voting and Plurality Voting With a Runoff.

Although preferential systems, notably STV, have been used in public elections to ensure proportional representation of different parties in legislatures, the vulnerability of STV to preference truncation illustrates its manipulability, and its non-monotonicity casts doubt upon its democratic character. In particular, it seems strange that voters can hurt an item's chances to win out by raising it in their rankings.

Although the Borda Count is monotonic, it is more readily manipulable than STV. Whereas it is difficult to calculate the impact of insincere voting on sequential eliminations and transfers under STV, the strategy of ranking the most serious opponent of one's favorite alternative last is a transparent way of diminishing a rival's chances under the Borda Count. Also, the introduction of a new and seemingly irrelevant item can have a confused effect, moving a last-place item into first place.

Although Cumulative Voting offers a means for conflicting groups to guarantee their approximate proportional representation, it requires good predictive abilities and considerable organizational efforts on the part of groups to ensure that their supporters concentrate their voters in the proper manner.

Because of the impossibility of satisfying a number of desiderata simultaneously, trade-offs are inevitable in the search for voting procedures that best meet different needs In this section, the author has tried to show how an understanding of certain characteristics of alternative voting procedures, especially those relating to their strategic properties, can facilitate the selection of practical procedures that satisfy the criteria one deems most important.

2.1.4 "Voting Equilibrium" – Strategic Comparison

Given the vulnerability to manipulation of the voting methods as discussed above, one would ask: How much information can one trust from the voting result? Is the one-time voting result the sincere reflection or intention of the voters? What happens if voters use strategic manipulation during their voting? What would happen if instead of traditional one-time voting, voters could vote on some issues more than once?

In a voting system in group decision-making settings, if voters are allowed to vote many times until certain criteria (such as deadline) are met, and if a feedback mechanism is provided so that voters can have access to substantial information through voting systems concerning the expressed preferences and voting intentions of others, then it is rational to hypothesize that this information can affect each voter's perception of the relative chances of the various decision-making alternatives being in contention for victory, which in turn can affect how the voters make their decisions. This is the idea of Human Dynamic Voting (HDV) proposed by the author. It is interesting to see the similar idea expressed by Myerson and Webber (1993) as "voting equilibrium". They also did a strategic comparison of voting equilibrium with three well-known voting methods: Plurality Voting, Borda Count, and Approval Voting.

Just as prices both summarize consumer demand and generate that same demand in a competitive equilibrium, so one might expect that, after a series of votes are reported, voters might eventually hold perceptions of the candidate's relative chances of contending for victory which both summarize the electorate's voting intentions, and generate vote totals which justify the voters' perceptions. From this perspective, Myerson and Weber (1993) developed the notion of a "voting equilibrium." A voting equilibrium arises in an "electoral situation" consisting of a set of candidates, a distribution of voters (indicating the proportions of the electorate holding different types of preferences), and a voting rule. The equilibrium itself consists of a set of relative probabilities of the election ending in a close race between any pair of candidates, and a specification of voting behavior for the various types of voters. At equilibrium, each voter is specified to vote in a manner which maximizes that voter's expected utility from the outcome of the election (given the perceived close-race probabilities), and the close-race probabilities are consistent with the candidate vote totals resulting from the specified behavior.

After proving that voting equilibriums exist in every electoral situation, Myerson and Weber (1993) determine the equilibriums under the Plurality Voting rule, Borda Count rule, and Approval Voting rule for a particular situation. Specifically, the situation has three candidates (1, 2, and 3), and three types of voters (A, B, and C). The utilities (u1, u2, u3) derived by a voter of any type from the election of any of the candidates are given in Table 2.4. Notice that voters A and B together make up a majority of the electorate, and prefer either 1 or 2. However, they could quite possibly split the vote, and hand the election to 3.

Table 2.4 Utilities Derived by a Voter

Voter type	Utility vector	Proportion of population
A	(10, 9, 0)	30%
B	(9, 10, 0)	30%
C	(0, 0, 10)	40%

Under plurality rule, three voting equilibriums exist. At one, all of the type-A and type-B voters cast their votes for candidate 1, and all of the type-C voters vote for candidate 3. The likelihood of candidates 1 and 3 being in a close race for victory is perceived by the voters to be much greater than the chance of any other pair of candidates being in a close race, and, since candidates 1 and 3 are the two highest vote-getters, the voters' perceptions are justified by the outcome. A similar equilibrium exists, wherein the type-A and type-B voters all vote for candidate 2.

However, there is a third voting equilibrium, at which all voters of each type vote for their most-favored candidate, and candidate 3 wins the election. The voters correctly perceive that close races between candidates 1 and 3, and between candidates 2 and 3, are of comparable likelihood and are much more likely than a close race between candidates 1 and 2 (the two lowest vote-getters), and these perceptions justify the voters' actions.

Under Borda's rule, a family of voting equilibriums exists. At all of these equilibriums, all three candidates are expected to draw roughly equal vote totals, but a close race between candidates 1 and 2 is perceived by the voters to be somewhat more likely than between candidate 3 and either 1 or 2. At equilibrium, each voter casts his or her 2-vote for his most-favored candidate. However, some type-A or type-B voters give the 1-vote to their second-most-favored candidate, while others give the 1-vote to candidate 3. (The close-race perceptions justify this behavior by making the type-A and type-B voters indifferent between casting the 1-vote for either of the two less-favored candidates.)

Under Approval Voting, three voting equilibriums exist. Two of the equilibriums are similar in outcome to the first two under the Plurality rule. One of candidates 1 or 2 draws approval votes from all of the type-A and type-B voters, the other draws approval votes only from the voters who most prefer him or her, and the type-C voters vote only for candidate 3. Since candidate 3 finishes with the second-highest vote total, the only justified perceptions are that a close race involving him and the likely winner are much more likely than any other close race. Yet, if some other close race were to develop, it is perceived to be much more likely to involve candidates 1 and 2 (the first- and third-place finishers) than candidate 3 and the third-place finisher. These perceptions in turn justify the voters' actions.

The third voting equilibrium resembles that found under Borda's rule. One-third of the type-A and type-B voters vote for both candidates 1 and 2, while everyone else votes only for his or her most-favored candidate. All three candidates are expected to draw roughly equal vote totals, but a close race between 1 and 2 is perceived to be nine times as likely as the close races between one of them and candidate 3. (These perceptions make type-A and type-B voters indifferent between single and double voting.)

What can be made of all this? Only under Approval Voting do all of the equilibriums involve every voter casting a ballot on which the votes for each candidate decrease monotonically with the utility derived by the voter from each candidate's election.

Approval Voting is the only voting system among the three studied under which there are equilibriums at which one of the first two candidates is the only likely winner, and at the same time there aren't any equilibriums in which candidate 3 is the only likely winner. Borda's rule fails to have the first of these properties, and the Plurality rule fails to have the second.

Under both Plurality Voting and Approval Voting, there remains room for the candidates to engage in political activities, which seek to influence voter perceptions of their "viability", in order to lead to a particular equilibrium outcome. Much computational work remains to be done to provide a more-complete picture of how the sets of voting equilibriums under these voting rules, and others, vary with the dynamic evolving of group voting process.

2.1.5 Arrow's Impossibility Theorem

Arrow's Impossibility Theorem (1951) is one of the most influential discoveries in electoral theory. If each individual in a group has his or her own preference towards a set of alternatives in the form of rank orders, is it possible for the group to reach group consensus? Under a set of axioms that intend to list conditions which a "reasonable" group consensus function should satisfy, Nobel Prize winner Kenneth Arrow's answer is "no"!

To explain Arrow's Impossible Theorem for k >= 3 alternatives, recall his 4 axioms:

- (U) (*Unrestricted Domain*) Every logically possible set of individual orders is included in the domain of the collective choice rule.
- (P) (*Pareto*) If every individual prefers any alternative a to another alternative b, then society must prefer a to b.
- (IIA) (*Independence of Irrelevant Alternatives*) The relative group ranking of any two candidates only depends upon the voters' relative ranking of this pair.
- (ND) (*No Dictator*) The group outcome cannot always be the same as the ranking of a particular voter.

Arrow starts by suggesting some reasonable sounding criteria for a good election method known as arrow's axioms. First of all, he felt that in a two-person election, the candidate with the most votes should win. This wouldn't be the case if the election was largely random, or if the real decision was made by a dictator or monarch.

Next he suggested that if one has an election where **A** wins, and introduces a new candidate **C**, then either **A** should still win, or **C** should now win. After all, the theory is, either the public prefers **A** to **C**, or **C** to **A**. If they prefer **C** to **A**, and **A** to everyone else, then **C** should win. On the other hand, if they prefer **A** to **C**, and **A** to everyone else, then **A** should win. It wouldn't make sense from this perspective if the addition of **C** caused **B** to win.

The problem is shown in the following example: 100 voters vote for items **A**, **B**, and **C**.

40	**A**	**B**	**C**
35	**B**	**C**	**A**
25	**C**	**A**	**B**

If the method chooses **A**, then one has to consider, "what if **B** wasn't running?" There would have been an election like this:

40	**A**	**C**
60	**C**	**A**

So, **C** would have won. But that is exactly the kind of thing that isn't allowed to happen. The introduction of **B** should have either caused **B** to win, or kept the result the same. The obvious conclusion is that a method can't choose **A** in the above situation, and meet Arrow's criteria. What about **B** and **C**?

If in a method **B** wins, see the following example: with the removal of **C, A** becomes the winner.

65	**A**	**B**
25	**B**	**A**

If in a method **C** wins, see the following example: with the removal of **A**, **B** becomes the winner.

75	**B**	**C**
25	**C**	**B**

So, no method can meet Arrow's rather sensible sounding criteria. Arrow concluded that if the voters' preferences are transitive and if the outcomes must be transitive, then the only procedure satisfying U, P, IIA is a dictator; that is, U, P, IIA, and ND are in conflict (Saari, D. G. 1995).

This theorem is quite startling, since at the first glance Axioms U, P, IIA, and ND seem quite reasonable. Given the negative result, there are a lot of approaches trying to justify it. One is to re-evaluate the axioms more critically. Another is to re-evaluate the settings in which the theorem is stated, and observe that Arrow's Theorem says that decision-making is impossible only in the sense that it is impossible to obtain a group ranking based on the input of individual rankings. Perhaps one could modify demands on either the input (individual rankings) or the output (group ranking) and still be able to make some sort of rational decision-making. For more detailed discussion of the possibilities, see Luce and Raiffa (1957).

Here is one example to explain the reasons of the paradox of voting discovered by Arrow. Imagine a fictional place of Arrovia with 100 citizens, some citizens have a car, others have a bicycle, and some have both.

48	Bike only
10	Bike and Car
42	Car only

The following statements are true:

- The majority of Arrovians have a Bike.
- The majority of Arrovians have a Car.

Can one then conclude,

- The majority of Arrovians have a Bike and a Car.

Obviously not, since this isn't true. But it would work if one replaced "the majority of Arrovians" with the person "Arrow".

- Arrow has a Bike
- Arrow has a Car

- Therefore Arrow has a Bike and a Car

The problem is that one is tempted to create an imaginary individual called "the majority of Arrovians" and ascribe various attributes to it. It is no surprise that "the public" might have contradictory views. "The public" isn't an individual; it's just a concept one made up.

2.1.6 Conclusion of Voting Theories

This section concludes that although Arrow's paradox of voting exists, rational voting is possible by carefully applying proper alternative voting methods. However, during the process, there are certain issues that need to be taken care of. It is necessary to choose appropriate voting methods in different decision-making settings, and to understand their problems and weaknesses, so that the voting process can truly help groups to explore the problem, and improve individual consistency among group members.

2.2 Scaling Theories

One major difficulty in social science research is how to choose the proper measurement instruments to scale uncertainty or ambiguity issues. Needless to say, all voting schemes have to be applied on certain scales. In this section, an overview of the basic considerations in scaling is provided to set the foundation for the treatment of these scaling models, and the focus is specially set on one scaling model – Thurstone's Law of Comparative Judgment.

2.2.1 Scaling: Theoretical Concepts and Approaches

There is a lot to say about the nature and types of scaling. Togerson (1958) has identified three characteristics of measurement of a property: order, distance, and origin. In his view, order is invariably involved in measurement as it is usually conceived (which is perhaps not true, since categorical data hardly have any order). In addition to order, a scale may possess either or both of the distance and origin. He thus got four types of scales as shown in Table 2.5 below:

Table 2.5 Types of Scales

	No Natural Origin	**Natural Origin**
No Distance	Ordinal scale	Ordinal scale with natural origin
Distance	Interval scale	Ratio scale

Any uni-dimensional scale falls into one or another of the four scale types: (1) ordinal, (2) ordinal with natural origin, (3) interval, and (4) interval with natural origin. The natural origin here could be thought of as an "anchor".

Similar to this classification is the one that given by Stevens (1951). Stevens distinguishes among nominal, ordinal, interval, and ratio scales. His nominal scale refers to the objects that can only be classified into categories with numbers used only to name the objects or name the classes of objects. He also didn't distinguish between ordinal scales with or without natural origins.

Another more complex classification of scales has been given by Coombs (1952). Coombs adds to Stevens' four types of scales a fifth, which he called a partially ordered scales, which falls between the nominal scale and the ordinal scale. A somewhat different classification has subsequently appeared in Coombs, Raiffa, Thrall (1954) and a lot of others. Here the author will combine Togerson and Stevens's classifications and discuss briefly the five types of scales below:

- *Nominal scale*: Given a number of discrete objects, simply assign a different numeral to each of them. This set of numerals corresponds to one kind of nominal scale. A second nominal scale would be obtained if the objects were sorted into a number of piles or classes, according to some pre-defined properties. Words can be used instead of numerals here.
- *Ordinal scale*: Given that the objects can be arranged in serial order with respect to the property, numbers are to be assigned in such a manner that the order of the numbers assigned agrees with that of the property.
- *Ordinal with natural origin*: Given, in addition to the above, that a unique natural origin can be established with respect to the property, numbers are to be assigned in such a manner that the order of the numbers assigned agrees with that of the property. But, instead of any monotonic increasing transform of the numbers, we are limited to those that leave the origin unchanged.
- *Equal Interval*: Given, in addition to the requirements of an ordinal scale, that one can also determine the differences between different amounts of the property (the distances), numbers are to be assigned in such a manner that the order of the numbers assigned agrees with that of the property, and further more, their differences reflect the sizes of the corresponding distances.
- *Ratio*: if the determination can be added in some sense of a unique natural origin to the requirements of the interval scale, then only one number can be

assigned arbitrarily. After one number has been assigned to one object, the numbers to be assigned to those objects remaining are completely determined, leave only the natural origin (zero point) unchanged.

The classification of scales into scale types was based on the underlying measurement types, such as: how much information about the property the numbers represented (which may depend on the nature of the property); or simply by arbitrary definition; or depening on laws relating to various quantities of the construct.

A considerable number of procedures have been devised to determine scale values of a series of objects, events, or individuals with respect to some attributes. While numerous distinctions can be made among scaling models, in this research, concentration is put on the following four main characteristics.

First, scaling models may be used for three related but distinct purposes (Coombs, 1964; Weisberg, 1974):

- Scaling analysis may perform a hypothesis testing purpose. In this case, the scaling model is used as a criterion to evaluate the relative fit of a given set of observed data to a specific model.
- Scaling may be employed for the purpose of simply describing a data structure, that is, for discovering the latent dimensions underlying a set of obtained observations.
- Developing a uni-dimensional scale on which individuals can be given scores, such as constructing a scale for measuring socio-economic status that could be correlated with a variety of attitudinal and behavioral measures.

While all the scaling models can be used in these three capacities, they differ in the extent to which they have been employed for these various purposes.

Second, scaling models can be distinguished according to whether they are intended to scale persons, stimuli, or both persons and stimuli (McIver, 1981). These may take the form of many subjects each responding once, one subject responding many times, or several subjects responding several times, to each of a number of stimuli or stimuli combinations.

- *The Subject-Centered Approach.* The systematic variation in the reactions of the subjects to the stimuli is attributed to individual differences in the subjects. The immediate purpose of the experiment is to scale the subjects, which alone are assigned scale values.
- *The Stimulus-Centered or Judgment Approach.* The systematic variation in the reactions of the subjects to the stimuli is attributed to differences in the stimuli with respect to a designated attribute. The immediate purpose of the experiment is to scale the stimuli, which alone are assigned scale values.
- *The Response Approach.* Variation of reactions to stimuli is ascribed to both variations in the subjects and in the stimuli. Both subjects and stimuli might be assigned scale values.

For example, Likert scale is a subject-centered approach since only subjects receive scale scores. Thurstone scaling is considered a method to evaluate the stimuli with respect to some designated attributes. It is the stimuli rather than the persons that are scaled (Togerson, 1958). Guttman scaling is an approach in which both subjects and stimuli can be assigned scale values (McIver, 1981).

The third important difference among scaling models relates to the type of data that is appropriate to the models. Coombs (1964) has indicated that there are four basic kinds of data.

- *Preferential choice data*: involves the ranking of objects (i.e. stimuli) according to some criterion or purpose. The scaling method is called rank order. For example, a group of individuals was asked to rank cities according to how desirable it would be to live in them. It is clear that preferential choice data represent a response approach to scaling since the ranking of objects according to the subject's preference necessarily involves both the subject's own position on the attribute and how the stimuli are perceived to relate to the attribute.
- *Single-stimulus data*: involves the subject responding to the stimuli one at a time. There is no explicit ranking or comparison of stimuli. For example, one would be asked whether he or she approves of a particular issue. Single-stimulus data, depending on their essential purpose, could be used to scale stimuli, subjects, or both stimuli and subjects. For example, Likert scaling is based on single-stimulus data and leads to the scaling of individuals. On the other hand, if individuals were asked to estimate the attribute of given objects one at a time, then, one could consider this process leading to the scaling of the stimuli themselves.
- *Stimulus comparison data*: In this situation, the individual is presented with a set of stimuli and asked to select the one that has more or less of the specific attribute in question than the others. The scaling method is called paired comparison. In this case the individual's own position or preference is not

directly engaged; instead, the evaluation is assumed to reflect differences among the stimuli, not the individuals. Thus, stimulus comparison data represent a stimulus-oriented approach to scaling.

- *Similarities data*: All pairs of stimuli are formed, and the individuals will be presented with these pairs and asked in which pair the members are more alike. In contrast to the other types of data, no instructions are given to individuals about the dimensions on which the dyads are to be compared. On the contrary, this is precisely what the researcher hopes to discover in his or her investigation. Similarities data also involve the scaling of stimuli, not individuals.

A fourth characteristic on which scaling models can be distinguished is whether the models are multi-dimensional or uni-dimensional in nature. The concept of dimensionality is complex, yet it is sufficient for one to understand at an intuitive level the distinction between uni-dimensionality and multi-dimensionality. Uni-dimensional scaling is relevant to those situations in which it is presumed that there exists a single, fundamental dimension underlying a set of observations (i.e., data items); versus multi-dimensional scaling explicitly allow for the possibility that there is more than a single dimension that underlies a set of observations. While multi-dimensional scaling models have more power and flexibility, there continues to be substantial interest in uni-dimensional scaling models since it's easier to understand and apply, and easier to handle in the research (McIVER, 1981).

Finally, an important distinction among scaling methods is the criteria used for choosing items to be included on the scale. These criteria are not the same for different scaling models, but differ depending on the purposes and assumptions of the scaling analysis. Above all, when measuring a variety of individual properties, the scales should be made up of multiple items rather than a single item. There are several reasons for this (Nunnally, 1978):

1. It is very unlikely that a single item can fully represent a complex theoretical concept or any specific attribute for that matter.
2. Single-item measure lack precision because they cannot discriminate among fine degrees of attribute.
3. Single-item measures are usually less reliable than multi-item scales. That is, they are more prone to errors.

The most fundamental problem with single-item measurement is not merely that they tend to be less valid, less accurate, and less reliable than multi-items. Rather, it is that they provide only a single measurement, yet people rarely have sufficient information to estimate their measurement properties. Thus, their degree of validity, accuracy, and reliability is often unknowable. The absence of this vital information can sometimes lead one to overlook the serious deficiency of single-item measures.

2.2.2 Thurstone Scaling

Thurstone scaling method represented a major advancement in the scaling of psychological stimuli (Thurstone, 1927). Building on his law of comparative judgment, Thurstone introduced three methods of scaling: paired comparisons, successive intervals, and equal-appearing intervals. While Thurstone scaling techniques were quite popular during the 1920s and 1930s, they are not employed widely today because of a number of limitations (Togerson, 1958; Luce 1994). However, many methods that have been used today are extensions of Thurstone's scaling method (White et al., 1999).

One main characteristic of the Thurstone scaling method is that Thurstone's Law of Comparative Judgment (Thurstone 1927; Torgerson, 1958) has the important quality of being able to transform rank order data or comparative preference data by individuals in a group to a single group composite interval scale. In so doing, it can convey to the group more information on the group position than many other ways of processing rank order data. When direct scales (such as a physical scale) are not available, by using human judgment, one could use either rank order or paired comparison to obtain an ordering of the preference of the objects based on the comparative judgments of the group of individuals. Then, by applying a set of mathematic equations, such binary or ordinal scale data could be turned into interval scale data, which can indicate the relative distances between the objects that have been judged. When applying Thurstone's scaling method, it is not assumed that each stimulus always evokes the same discriminal process for different individuals or even for the same individual at different times.

There are very important practical reasons to employ the Thurstone scaling method. First of all, in many GDSS researches, it is much more difficult to ask individuals for ratio or interval scales. However, it is relatively easier and more accurate to ask individuals to rank order items, such as objectives or goals. For example, in many cases the appropriate judgment one wishes to solicit from an individual is a ranking (i.e., ordinal scale measurement) of a set of comparable items. A person can estimate that a particular goal is more important than another one; however, it is much more difficult for individuals to estimate consistently how much more important one single item is. A scaling method such as Thurstone's Law of Comparative Judgment can transform individual judgments of rank orders and produce one single group result which is an interval scale rather than a rank ordered scale. The interval scale can provide not only a rank ordered result, but also the distance between individual items. Providing the group the results in terms of this interval scale allows the individuals to detect the clusters or patterns of distribution of the item in a much more reliable manner. For example, one can tell from the interval scale that certain objectives are clearly distinct from other objectives, and which are considered in closer proximity. Merely providing an averaging of the ranking scale would conceal such valuable information.

Furthermore, standard average/mean methods can lead to inconsistencies in group judgments (i.e., Arrow's Paradox). This can occur when there are conflicts underlying the average/mean data, or when there is a lack of appropriate "anchoring" of the scales. Thurstone's Law of Comparative Judgment provides a way to look into the degree of agreement/consensus or disagreement/conflict from a new point of view.

In addition, traditionally the development of scaling methods has been to determine an absolute measurement of human response where one assumes the human does not change. For example, the use of surveys for psychological scales or consumer preferences in marketing studies never took changes into consideration, while it is quite possible the user attitudes/preferences could be fluid and fluctuate in many cases. Thurstone scaling has the advantage of admitting and allowing such changes.

In group support systems and the original Delphi method (Linstone & Turoff, 1975), there is a completely different objective: How to use these human judgment measuring instruments to provide feedback to the individual on the implications of their judgment and feedback to the group to expose consistencies (e.g., agreement) and inconsistencies (e.g., disagreement) in the resulting group judgment. (Note that consistency is a broader concept than agreement.)

Arrow's Theorem says that decision-making is impossible only in the sense that it is impossible to obtain a group ranking based on the input of individual rankings. Arrow's paradox may limit the ability to define a single perfect measurement instrument in a group setting, but it does not prevent the use of multi-instruments that complement one another and exhibit different properties of the group judgment under different conditions. In this sense, researchers have proposed one possible solution to look at group consistencies in a group support system: allow the group consensus function to choose several possible consensus rankings, rather than just one. This means Thurstone scaling method needs to be used in accompany with other measurements, such as Condorcet, Borda Count, etc., in order to gain more insight than just one, and to overcome the certain limitations that a single measurement may introduce. Yet the group needs to understand these methods and understand further whether there were small or large differences underlying the resulting same point on the scale. The exact sense of small or large will depend on the situation of the application.

2.2.3 Thurstone's Law of Comparative Judgment

Thurstone was mainly concerned with the fundamental problem of how psychological stimuli could be measured and compared with one another. The measurement of physical objects, in contrast, is simple and straightforward. If a scientist wanted to discover the weight of each of a set of objects, for example, he simply placed each object on a scale and recorded its measurement weight. The resulting objects could then be ordered from the lightest to the heaviest. If no scale was available, however, the process of ordering the objects by their relative weights becomes considerably more problematic because it unavoidably involves individual judgments. One could, for example, ask each of a group of individuals to arrange the objects from the lightest to the heaviest by having each individual lift each of the objects one at a time. Alternatively, one could present the objects in all possible pairs and ask each person which member of the dyads was the heavier. In either case, one could obtain an ordering of the weight of the objects based on the comparative judgments of the group of individuals.

Thurstone recognized that this was precisely the situation of the social scientist attempting to measure psychological (non-physical) stimuli – measuring the weight of objects without the use of a scale. And the solution must also lie in the use of human judgments. To take a practical example, consider the situation in which a group of individuals is given a list of occupations and asked to evaluate each according to its relative prestige. The list of occupations represents the stimuli, and the presumption is that each can be ordered along a psychological continuum with respect to the degree of prestige each possesses. The law of comparative judgments presumes that for each stimulus – in this case, each occupation – there exists a most frequently occurring response, which is referred to as its modal discriminal process on the psychological continuum. Stated most simply, each individual makes a discrimination or response involving a judgment as to the relative degree of prestige of each occupation. It is not assumed that each stimulus always evokes the same discriminal process for different individuals or even for the same individual at different times. Thus, while the occupation of medical doctor will elicit a modal response from the group of individuals as regards its prestige, this modal discriminal process will not characterize all of the responses. It is typically assumed that the distribution of all discriminal processes aroused by any given stimulus is normal about the modal discriminal process. The normal distribution can be described by two parameters – its mean and standard deviation. Moreover, the mean, median and mode have the same value for any normal distribution. The mean discriminal process is taken as the scale value for the particular stimulus, and its standard deviation is designated as the discriminal dispersion for the stimulus. Any two occupations may thus differ in terms of their modal discriminal process, that is, their scale values and their modal dispersion. Now the list of occupations can be ordered along the psychological continuum representing prestige by calculating their scale values and arranging them from most to least prestigious.

The basic assumption underlying the law of comparative judgment is that the degree to which any two stimuli can be discriminated is a direct function of the difference in their status as regards the attribute in question. To continue with the example, presumably most respondents would judge the medical doctor to be higher in prestige than the automobile mechanic. Their relative scale scores would reflect this difference. If two stimuli are judged to have exactly the same scale score – that is, one half of the respondents considering occupation A to be more prestigious than occupation B, and the other half judging B to be more prestigious than A – then they are considered to have the same amount of the property. Thus, the placement of occupations on the prestige continuum should reflect the degree to which respondents can discriminate among the perceived prestige of the various occupations. The greater the distance between any two occupations on the continuum, the greater the extent to which the respondents have agreed that one of the occupations is more prestigious than the other occupation. Conversely, the smaller the distance between any two occupations on the continuum, the more confusion exists about the relative prestige of the two occupations. The degree to which any two occupations can be discriminated is a direct reflection of their perceived differences in the prestige.

Each of the three scaling methods developed by Thurstone – the method of paired comparisons, the method of successive intervals, and the method of equal-appearing intervals – may be considered a different operationalization of the basic Law of Comparative Judgment.

2.2.3.1 The Law of Comparative Judgment. The law of comparative judgment is a set of equations. They relate to the proportion of times any given stimulus ***k*** is judged greater on a given attribute than any other stimulus ***j*** to the scale values and discriminal dispersions of the two stimuli on the psychological continuum. Based on those postulates discussed above, the mean and standard deviation of the distribution associated with a stimulus are taken as its scale values and discriminal dispersion, respectively.

All forms of the law of comparative judgment assume that each stimulus has been compared with each other stimulus a large number of times. It is assumed that the conditions is that many subjects each judge each pair once, so the interest is in the "average" scale for a population.

When applying Thurstone's Law of Comparative Judgment in controlled experiments, in order to obtain unbiased results, one needs to be cautious on any possible bias. Below are some of the precautions:

- Keeping pairs having one stimulus in common maximally separated in the order of presentation.
- Arrange pairs so that "correct" responses are approximately evenly divided between first and second members of the pairs.
- Arranging pairs so that there is no detectable systematic pattern of "correct" responses.
- Arranging pairs so that there is no systematic variation in difficulty of judgment.
- Varying the order of presentation from trial to trial to eliminate serial learning of response pattern.

Assuming constant variance of distributions of discriminal differences, the following equation of the law of comparative judgment can be obtained:

$$s_k - s_j = cx_{jk}(j,k = 1,2,\cdots,n)$$

Where

- S_j and S_k denotes the scale values of the two stimuli ***j*** and ***k***,
- x_{jk} is the unit normal deviation corresponding to the theoretical proportion of times stimulus ***k*** is judged greater than stimulus ***j***.
- *C* denotes the constant standard deviation of the distribution of discriminal differences.

After each of the n(n-1)/2 pairs of stimuli have been presented a large number of times, the number of times each stimulus was judged greater than each other stimulus was obtained as raw data. These observed frequencies may be arranged in the n×n square matrix **F**. The general elements f_{jk} in the matrix **F** denotes the observed number of times stimulus ***k*** was judged greater then stimulus ***j***. Matrix **P** is constructed from matrix **F**. The element p'_{jk} is the observed proportion of times stimulus ***k*** was judged greater then stimulus ***j***. Diagonal cells are ordinarily left vacant. From matrix **P** is constructed in turn matrix **X**, the basic transformation matrix. The element x'_{jk} is the unit normal deviate corresponding to the element p'_{jk}, and maybe obtained by referring to a table of areas under the unit normal curve. Proportions of 1.00 and 0.00 cannot be used since the x value will be unboundedly large. When such proportions occur, the corresponding cells in matrix **X** are left vacant. Zeros are entered in the diagonal cells since ordinarily it was assume that S_k - S_k = 0. Matrix **X** contains the sample estimates x'_{jk} of the theoretical values found in the equation of the law of comparative judgment.

The usual procedure for obtaining estimates of scale values from a matrix X which contains no vacant cells is a least-squares solution. The result is:

$$s'_k = \frac{1}{n}\sum_{j=1}^{n} x'_{jk} \, (k = 1, 2, \cdots, n)$$

Therefore, a least-squares estimate of the scale values can be obtained simply by averaging the columns of matrix **X**.

For incomplete data, the calculation is more complex, however, the basic concept is the same as discussed above.

2.2.3.2 Limitations of Thurstone Scaling Method. While Thurstone's scaling method represented a major contribution to the systematic measurement of attitudes, the approach proved to be problematic in a number of regards.

First, the method assumes that the items have determinate scale positions that are the same for subjects as judges (Scott, 1968). However, judges are asked to respond to the items not in terms of their own attitudes towards the phenomenon (as are subjects), but in terms of the placement of the items on the continuum. As Scott (1968) observes, "the model requires that differences in judged location of a particular item are 'random' and do not depend on systematic characteristics of the judges." Yet, it has been found that judges with extremist attitudes toward the phenomenon, either positive or negative, do not discriminate effectively among moderate items (Scott, 1968). More generally, it is often unrealistic to presume that a judge's own attitude is independent of his item judgments, as required by the model.

Second, since the tasks for the judges and subjects are different, there is a substantial possibility that the intended dimension may not determine the subjects' responses to the items. In other words, subjects may well respond to the items for reasons that were unanticipated in the construction of the scale, resulting in an invalid measuring instrument.

A related limitation of Thurstone scaling is that it presumes but provides no direct evidence of the uni-dimensionality of the scale. Thurstone focused on the assignment of the items along the dimension, but took for granted that a person's responses could be adequately represented on the same dimension.

Finally, the construction of Thurstone scales requires an inordinate amount of labor because of both the use of judges and the need to assign scale values to each of the original items. Thus, as a pragmatic matter, it is often easier and simpler to construct equally reliable scales based on other methods.

2.2.4 Summary of Scaling Theories

In this section, first, the theoretical concepts and approaches of scaling were discussed, laying the groundwork for adopting scaling methods into voting procedures. Then the discussion is focused on one method – Thurstone's Law of Comparative Judgment. The unique features of this method and how to apply it, and the limitations of this method were further discussed. This justification is both necessary and helpful in employing scaling methods for the Social Decision Support System (SDSS) toolkit developed by the author (i.e., Zheng Li) in this dissertation.

CHAPTER 3

VOTING TOOL IMPLEMENTATIONS

Voting tools have been identified as a necessary part of many group decision support systems (GDSS), electronic meeting systems (EMS), groupware systems, etc. Although voting theories can be very complicated, the current voting tool implementations are relatively simple and straightforward so far in most applications. Very little is done on either to providing the insight of underlying voting theories and methods, or to support multiple voting methods. In this chapter, several implementations of voting tools are reviewed, and their application areas and main features are highlighted.

3.1 Reported Voting Tool Implementations

3.1.1 Reported Voting Systems

To show the potential areas where voting tools are active parts, several different systems that have been reported in referred publications, which contain a discussion of voting tools, are reviewed in this section.

The University of Arizona GroupSystems EMS The Electronic Meeting System (EMS) developed by University of Arizona has a voting tool that supports idea generating, and gives the priority of each idea in the idea-generating list (Nunamaker et al., 1991). However, no detail about the voting tool was available in their paper.

The COCA model COCA (Collaborative Objects Coordination Architecture) is a generic framework for developing collaborative systems. It contains a modest set of tools for Electronic Meeting Systems (EMSs) to show how they can be used to support both unstructured and structured meetings, with only changes in the coordination policies and no changes to the tools themselves (Li et al., 1999). A voting tool could help multi-users decide whether or not they can control an item within a meeting.

Meeting Manager Meeting Manager is a meeting management and legislative voting system designed for the Edmonton, Alberta (Canada) City Council. It is a workflow-oriented performance support system, providing information needed in council meetings, coordinating and recording the Council's votes and other activities. The system is implemented on personal computers with touch screens embedded in the work surfaces of the Council chambers. This system replaced a simple electro-mechanical system that permitted three interactions: a "yes" vote, a "no" vote, and a request to speak (Computing Resources Department, City of Edmonton, 1996).

Movie Recommender System The movie recommender system (Ghosh et al., 1999) provides the following major functionalities to its users: (1) Storing of user preferences. (2) Recommend movies based on the stored preferences. Movies to be suggested are selected by a combination of voting and nearest neighbor algorithms based on the user specific knowledge available to the system. They have adapted methods developed in the voting theory literature to find compromises between possibly disparate preferences. Voting schemes allow users to find compromises with some guarantees regarding the nature of the tradeoff. They are also robust to small errors in estimates of user preferences. With the guarantees provided by the voting scheme, the movie recommender system can generate convincing arguments for recommending a particular movie when its associated user asks for an explanation. The capability to provide a formal explanation of agent behavior has been an added incentive for the use of voting techniques in this implementation. The system has chosen Black's voting rule: choose a Condercet Winner if one exists, otherwise choose option with highest Borda count.

"Coordinating Distributed Actions via Agent Voting"(Urken, A. B., 1990) This paper investigated the use of voting policies to coordinate routing decisions in a phone network. Although the social metaphor of voting has been applied to network coordination decision tasks, this study presented the first operational example of a vote-theoretic group decision support system (GDSS) for nodes. The Monte Carlo experimental evidence shows that a collective choice voting policy dominates a policy of individual, hierarchical voting in minimizing movement toward system saturation and promoting load balancing. This result provides a basis for using voting policies to create more complex self-correcting networks.

"Social Choice Theory and Distributed Decision Making"(Urken, A. B., 1988) This paper discussed the strategies of distributed decision making based on social choice theory that could be used to create a balance between organizational complexity and uncertainty. Although group decision support systems (GDSSs) have included options for making human collective choices, their design has not been based on optimal rules. Social choice theory can also be used to improve the reliability of decisions made by nodes in distributed computer networks. Three examples illustrate the application of this theory: human computer-mediated distributed decision making, electing a coordinator to reorganize a failed distributed network, and using weighted votes to improve network reliability. Voting as a common analytic framework is further discussed in this paper.

"Knowledge Acquisition: Issues, Techniques, and Methodology"(Liou, Y. I. 1990) The application of expert systems in organizations has increased dramatically in recent years. The power of these expert systems mainly derives from the knowledge they possess rather than the inference mechanism they employ. Knowledge acquisition is the process of extracting knowledge from experts and structuring this knowledge into a computer readable form. To ensure the performance of an expert system, the acquisition of knowledge becomes the most essential task in the development process. This paper first discussed the selection of domain experts; the roles of the knowledge engineer, users and managers, and factors related to a decision of whether to use single or multiple experts. Knowledge acquisition techniques including interviewing, observations, protocol analysis, discourse analysis, repertory grid analysis, brainstorming, Nominal Group Technique, Delphi technique, consensus decision-making, and computer-aided group sessions were then reviewed. Difficulties of employing these techniques were discussed. A knowledge acquisition methodology that was developed to layout a systematic approach to acquiring knowledge from domain experts was described next. This methodology had four phases: planning, extraction, analysis, and verification. The paper concluded with trends in knowledge acquisition.

The consensus decision-making technique focused on finding a compromise solution to a problem. It was equivalent to the voting technique. It involved presenting a problem to domain experts and encouraging each member to vote on alternative solutions to the problem. Alternatives were ranked and rated by the group of experts. It was effective only if each expert who participates in the team feels that his or her views and opinions have been heard. It was also vital that each expert have a commitment to the group decision even though he or she may have some reservations. Even when one best answer may not be agreed upon by the team, this technique can significantly contribute to knowledge base development efforts.

The paper also discussed Voting and pointed out that the voting technique can be used in defining problem scope, identifying alternative solutions, and soliciting proper solutions. For the technique to be effective, the knowledge engineer had to be aware of the possible effects of status, rank, or experience differences among the domain experts.

"MessageWorld: A New Approach to Facilitating Asynchronous Group Communication"(Rose et al., 1995) This paper described a prototype system called MessageWorld designed to offer a new approach to online communication. It provided an alternative to traditional group information sharing tools such as e-mail, online bulletin boards, and searchable storage archives. It relieved message authors of the burden of addressing, while prospective readers were relieved of the burden of searching; the system provided a rendezvous mechanism for uniting readers with messages of interest to them. The systems relied on a variety of techniques including traditional content analysis and the correlation of user preferences. Adaptive algorithms served to incorporate some of the knowledge of the user community in the system's assessment of each user's interests. Voting tools were used to reflect the user preferences. The system incorporated a voting mechanism whereby each user expressed an opinion on each item read. Voting patterns were identified, and lists after voting were displayed automatically. The system design concerned how to encourage users to vote, and how to represent the voting process. It tried to integrate the voting process seamlessly into the interface, and allows users to vote directly to the messages.

"Preference-Based Decision Making for Cooperative Knowledge-Based Systems"(Wong, S. T. C., 1994) Recent advances in cooperative knowledge-based systems (CKBS) offer significant promise for intelligent interaction between multiple AI systems for solving larger, more complex problems. This paper proposed a logical, qualitative problem-solving scheme for CKBS that uses social choice theory as a formal basis for making joint decisions and promoting conflict resolution. This scheme consisted of three steps: (1) the selection of decision criteria and competing alternatives, (2) the formation of preference profiles and collective choices, and (3) the negotiation among agents as conflicts arise in the group decision-making. The preference scheme used voting methods. The simple majority rule that states that all criteria are of equal weight and thus have equal vote, was adopted as a default method in the scheme. This method, however, did not imply that all agents had equal voting power. The voting power of an agent on a particular problem was proportional to the number of its criteria listed in the problem agenda. In addition, when the criteria were of different importance, the weight majority rule was applied instead. The preference profiles and aggregated orderings were common knowledge among all agents. Every agent allocated a working space on its terminal screen to display and manipulate such common knowledge in real time. This interface was essential in the negotiation step.

3.1.2 Summary of the Reported Voting Systems

The various reported voting systems presented above indicted that:

Voting tools have been integrated/used into many kinds of different group support systems. Besides modern political voting systems for legislation, these different systems could be EMS, GDSS, groupware systems, or other systems, such as recommender systems, knowledge-based expert systems, etc. The potential application area of voting tools is still to be explored as democratic decision-making grows.

The voting tools listed above can be summarized in Table 3.1 below on the application areas, the voting methods used, and whether or not they have been implemented.

Table 3.1 Summaries of Voting Tool Implementations

Application	Method	Implementation
Voting on a list of items	N/A	Yes
Voting on whether or not they can control an item within a meeting	N/A	Yes
Voting on "yes", "no', or request to speak	N/A	Yes
Voting on preference	Black's voting rule: choose a Condercet Winner if one exists, otherwise choose option with highest Borda count.	Yes
Using voting policies to coordinate routing decisions in a phone network	Collective choice voting vs. individual, hierarchical voting	Yes
Using weighted votes to improve network reliability.	N/A	Recommended
Using preference voting in defining problem scope, identifying alternative solutions, and soliciting proper solutions in knowledge discovery systems	N/A	Proposed (theoretically)
Voting on preference	N/A	Prototype
Preference voting in negotiation	Simple majority rule / weighted voting	Proposed

From the table above, it is clear that only three papers reported the voting methods that have been used, and tried to compare the different methods. Only one paper (Liou, Y. I., 1990) tried to explore the application of voting tools in the group decision support process, while another paper (Rose et al., 1995) discussed integrating voting systems into on-line communication systems and some other design issues. They touched on the design topic such as how to encourage users to vote, and how to represent the voting process, and how to integrate voting seamlessly into the interface, etc.

Although the importance of voting tools in group support systems has been largely acknowledged, the real implementation is still sparse. As discussed in the Introduction Chapter, in the GDSS studies of both controlled experiments and field studies, over 40 research studies used voting tools, yet most of them implied the voting tools are standard packages that contain the simple and similar functions; only a few reported how they had used them; and very few describe the voting theories and potential limitations/problems. As shown above, very few did any analysis on the voting tools, and the details of voting tool implementation are rarely reported.

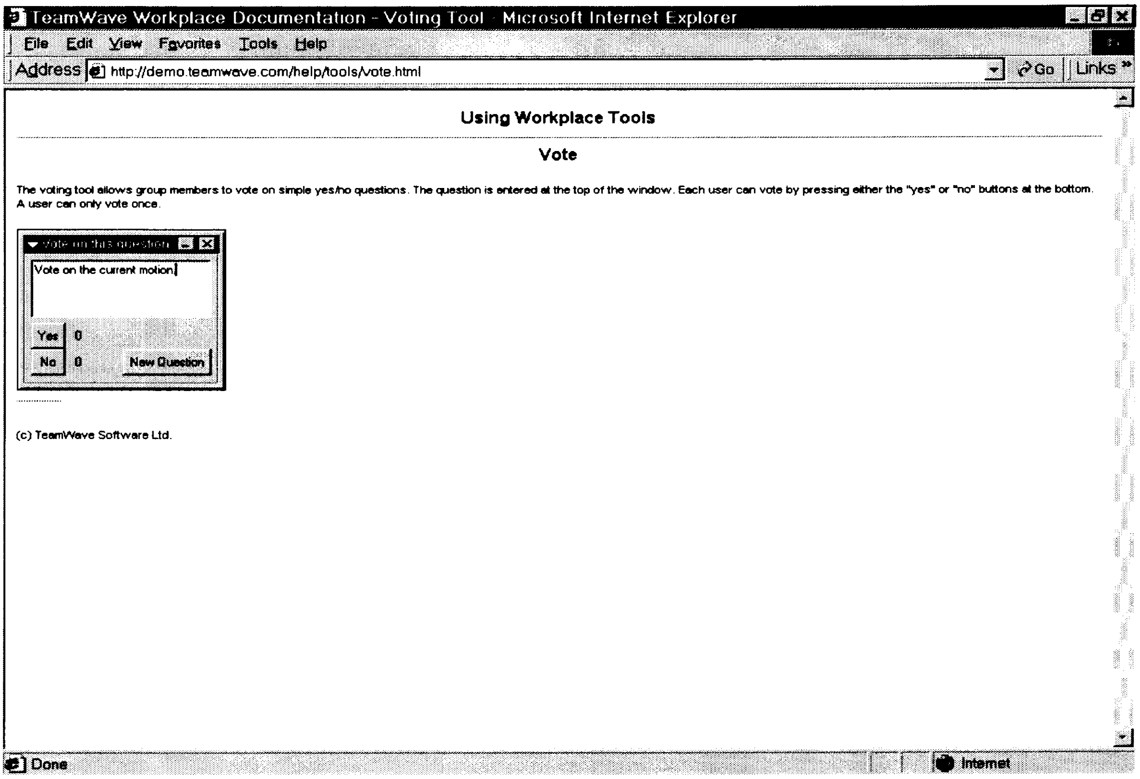
Finally, recent research on voting systems is not very much reported, as can be found in the year of the publications listed in the previous section.

3.2 Voting Tools on the Web

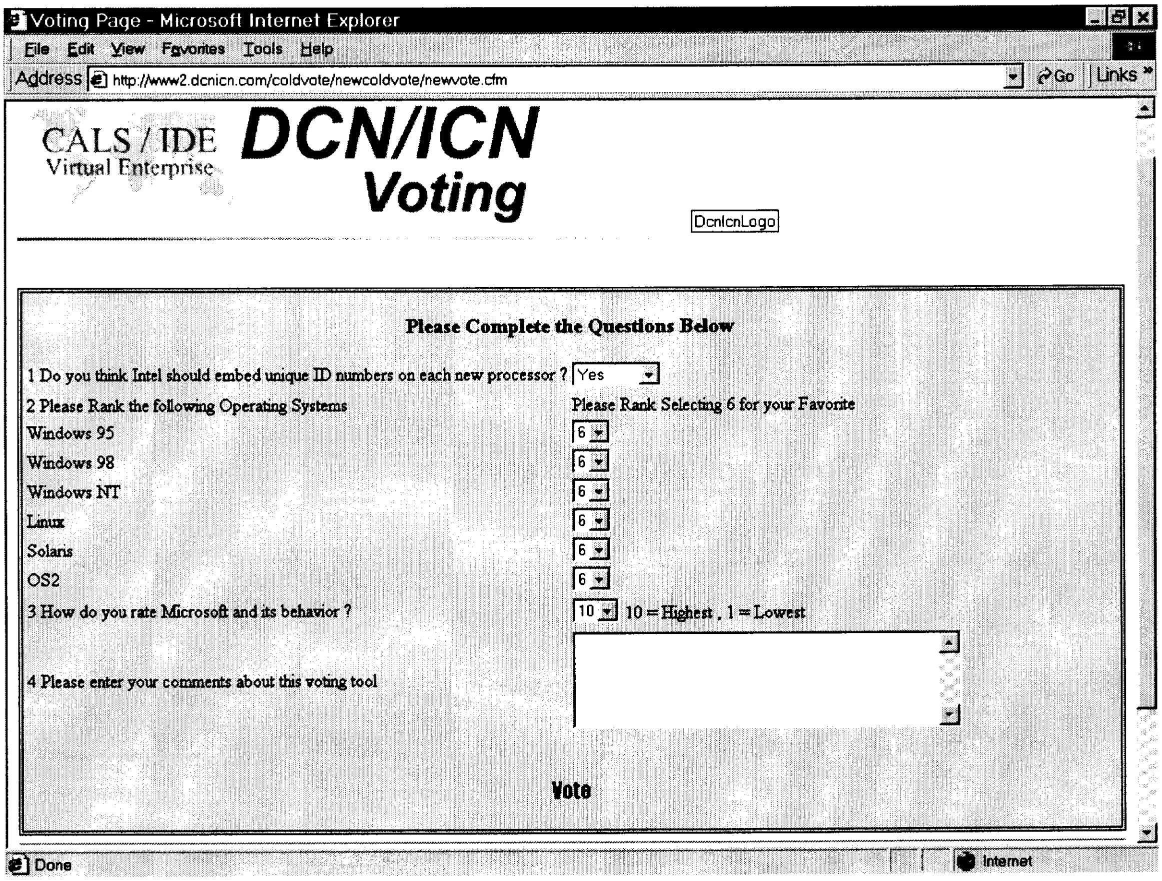
3.2.1 Sample Voting Tools on the Web

There are many kinds of voting tools available on the World Wide Web with rich features. Several Web-based voting tools and their main features are discussed in this section.

Workplace Voting Tool (URL: http://demo.teamwave.com/help/tools/vote.html. Retrieved 06/2001.) By TeamWave Software Ltd. This is a quite simple voting tool. The voting tool allows group members to vote on simple "yes/no" questions. The question is entered at the top of the window. Each user can vote by pressing either the "yes" or "no" buttons at the bottom. A user can only vote once. Below is a screenshot of the tool.



CAIS/IDE Virtual Enterprise DCN/ICN Voting Tool By West Virginia Technology Center (URL: http://www2.dcnicn.com/coldvote/newcoldvote/default.cfm. Retrieved 06/2001.) This voting tool has a neat user interface. The demo interface shows that it supports "yes/no" voting, rank order voting, semantic differential scaling, and open-ended comments. A demo of the CAIS/IDE Virtual Enterprise DCN/ICN voting tool is accessible online. Below is a screenshot of the demo.



The On-line Preferendum – a tool for voting, conflict resolution and decision-making (URL: http://www.qub.ac.uk/mgt/papers/prefer/index.html. Retrieved 06/2001.) This tool has been put on line by David Newman in Northern Ireland since May 1999. The Preferendum is a multi-option decision-making process which involves a debate, a vote, and an analysis of that vote. Below are some screen-shots of the interface of the Preferendum.

Preferendum Maths - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address http://www.qub.ac.uk/mgt/papers/prefer/prefcalc.html Go Links

Alternative systems for calculating winners of multi-option votes

- 14 people (J, K, L, M, N, P, Q, R, S, T, U, V, W, X)
- 4 options (a, b, c, d)
- cast preference points
  1. 4 points (like most)
  2. 3 points
  3. 2 points
  4. 1 point (like least)

	J	K	L	M	N	P	Q	R	S	T	U	V	W	X
4 pts	a	a	a	a	a	b	b	c	c	c	d	d	d	d
3 pts	b	b	b	b	c	d	d	b	b	b	c	c	c	c
2 pts	c	c	c	c	b	c	a	d	d	a	b	b	b	b
1 pt	d	d	d	d	d	a	c	a	a	d	a	a	a	a

Calculate winners by these systems: majority, STV, Condorcet, Preferendum

Results

On balance, in this hypothetical instance and in many actual scenarios:

System	Winner	Comment
Majority	a	quite inadequate
Alternative (STV)	d	often produces somewhat random results
Condorcet	c	fair, occasional 'paradox of voting'
Preferendum (Borda)	b	fair

In many cases the Borda preferendum and Condorcet results will actually coincide. Furthermore, if they do, one can rest assured that the ballot paper was fair and unclouded by any 'irrelevant alternative'.

Done Internet

Preferendum Maths - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Plurality or majority voting

We only consider the top row, so 'a' is the winner.

a	5
b	2
c	3
d	4

Alternative or Single Transferable Vote (STV)

We eliminate the least popular option, in this case 'b', and transfer its votes as P and Q would wish, namely to 'd'; the process continues until one option gets 50% + 1 of the vote.

So 'd' is the winner.

Count:	1st	2nd	3rd
a	5	5	+1 = 6
b	2	-2 = 0	-
c	3	3	-3 = 0
d	4	+2 = 6	+2 = 8

Condorcet

Under Condorcet we compare each pair of options in turn. J prefers 'a' to 'b', as do K, L, M and N, but P and Q prefer 'b' to 'a', as does everyone else. So when we compare the number of times 'a' or 'b' are ranked higher, we get a ratio of 5:9, so 'b' is more popular than 'a' which we denote by saying a < b.

Therefore c > b > d > a, so 'c' is the winner.

a:b = 5:9, so a < b
a:c = 6:8, so a < c
a:d = 6:8, so a < d
b:c = 6:8, so b < c
b:d = 10:4, so b > d
c:d = 8:6, so c > d

Preferendum

Under the preferendum we add up all the points cast for each option. 'a' got five 4s, no 3s, two 2s and seven 1s for a total of 31.

So 'b' is the winner.

	Voters					Points				
	a	b	c	d	Max.	a	b	c	d	Max.
4s	5	2	3	4	14	20	8	12	16	56
3s	0	7	5	2	0	0	21	15	6	0
2s	2	5	5	2	0	4	10	10	4	0

Previous Internet

David Newman concluded that computerized voting could provide more complicated voting procedures other than simple majority. But there is a danger. It is easier to implement the actual balloting and vote count than the whole process of voting, from choosing the question to implementing the agreed decision. He recommended considering voting at 5 levels:

1. The individual actions of the voting database API: add vote, replace vote, add option, calculate total (by different systems).
2. The client-server communication messages which trigger these actions and report the results.
3. The voting scripts or templates that integrate lower level actions into a voting cycle. This focuses on the vote itself and the mathematics of the chosen voting system.
4. Voting protocols or procedures. This includes both human and computer elements before and after the vote. E.g. we could have management protocols for getting options from a discussion, refining the list, doing a vote, calculating results according to an appropriate voting system, then interpreting the results.
5. Problem-solving integration. Here we integrate voting, rating and discussion in the context of group problem-solving or decision-making.

When using Preferenda during consensus politics meetings, the meeting is designed to embody the Preferendum vote as part of a social process so all levels are specified. David Newman further suggested that anyone implementing voting on the

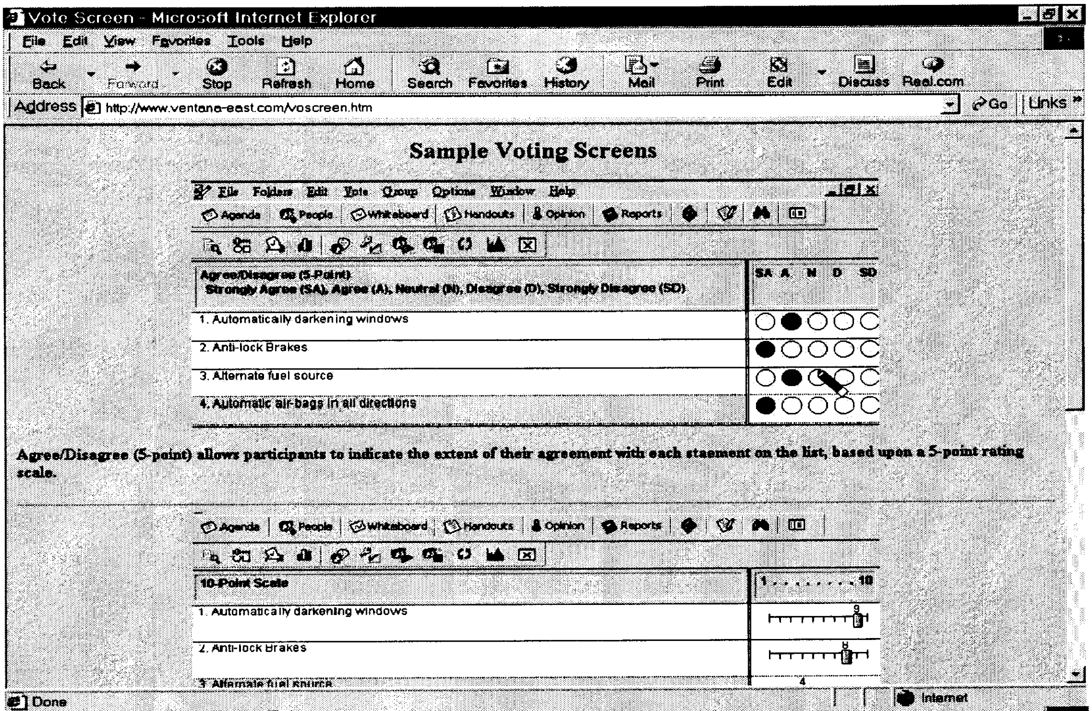
Internet should similarly design for all the levels. Among other things, the designers should consider:

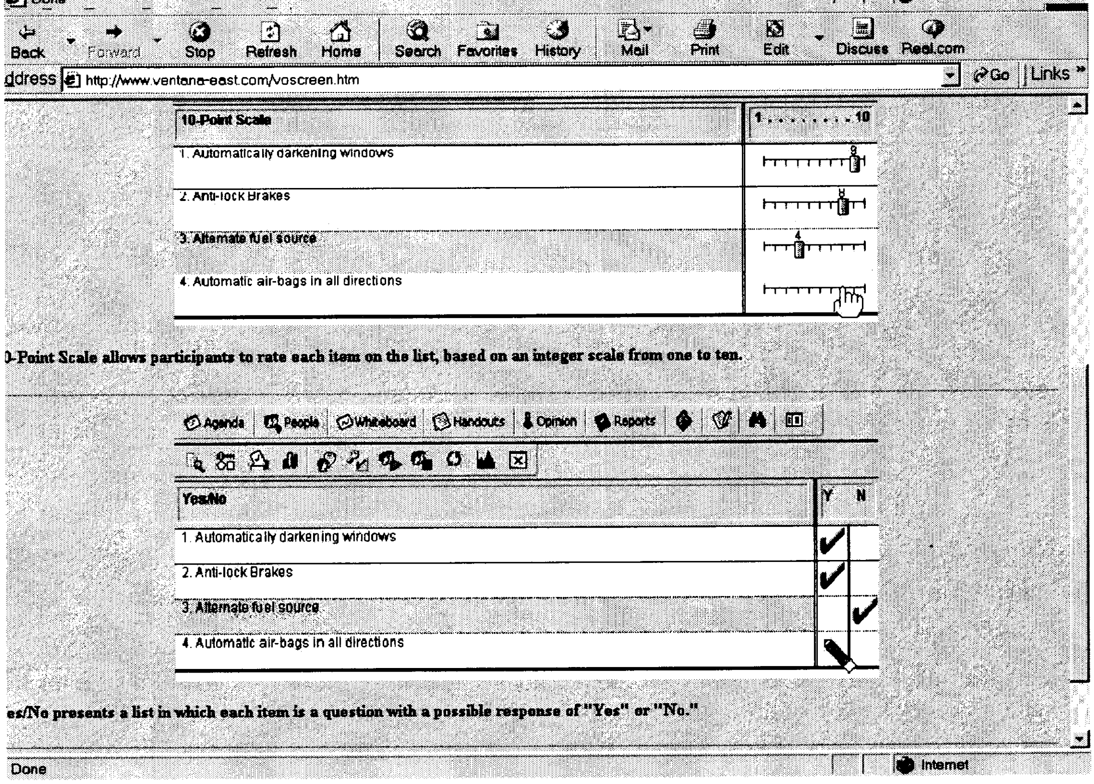
- Is the object to:
  - Make a choice between alternatives (=> ranking),
  - Or measure opinions (=> approval rating)?
- How are the questions and options decided, and by whom?
  - Automatic collection and use,
  - Imposed by decision implementers, or
  - Suggested by participants, collated by consensors/facilitators/moderators.
- When the votes are counted, is it more important that:
  - There are clear winners and losers (=> majority systems),
  - Or the choice is acceptable to everyone (=> consensus systems)?
- After the vote, will the choices be:
  - Implemented at once (=> representative voting between real choices),
  - Or be used in further discussion or negotiation (=> memetic evolution of new ideas)?

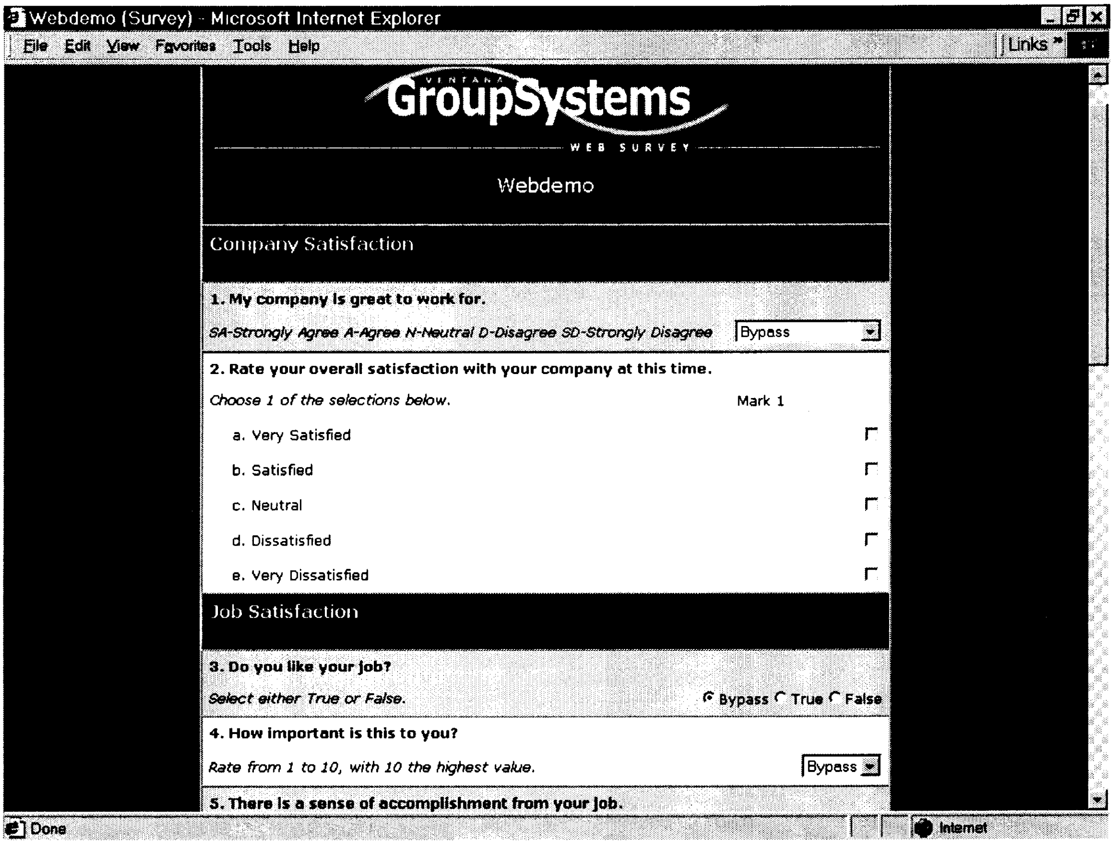
The Preferendum is appropriate to situations where one wants to rank choices and get consensus agreement on where to go next. The mathematics of the Borda preferendum reward consensus-seeking options over divisive ones. The whole discussion and voting process ensures that participants feel that they own the options and the outcome of the preferendum. In particular, the independent human consensors play an important part in moderating the discussion, reducing options to avoid information overload, preventing the preferendum being biased through multiple similar options, and in interpreting the results in human terms. It is worth implementing on the Internet in this fully developed form. It is not a mere multiple-choice referendum with majority voting or STV, as some imagine.

The Ventana East Corporation's GroupSystems Electronic Meeting Software (URL: http://www.ventana-east.com/default.htm. Retrieved 06/2001.) GroupSystems is a comprehensive set of group problem-solving tools that runs on interconnected personal computers. From issue exploration to final decisions, it provides structure and focus for any team's collaborative efforts. GroupSystems provides software tools that support the following functions: idea generation, idea organization, idea evaluation, issue analysis and exploration, and information management. This is a relatively sophisticated voting tool implementation.

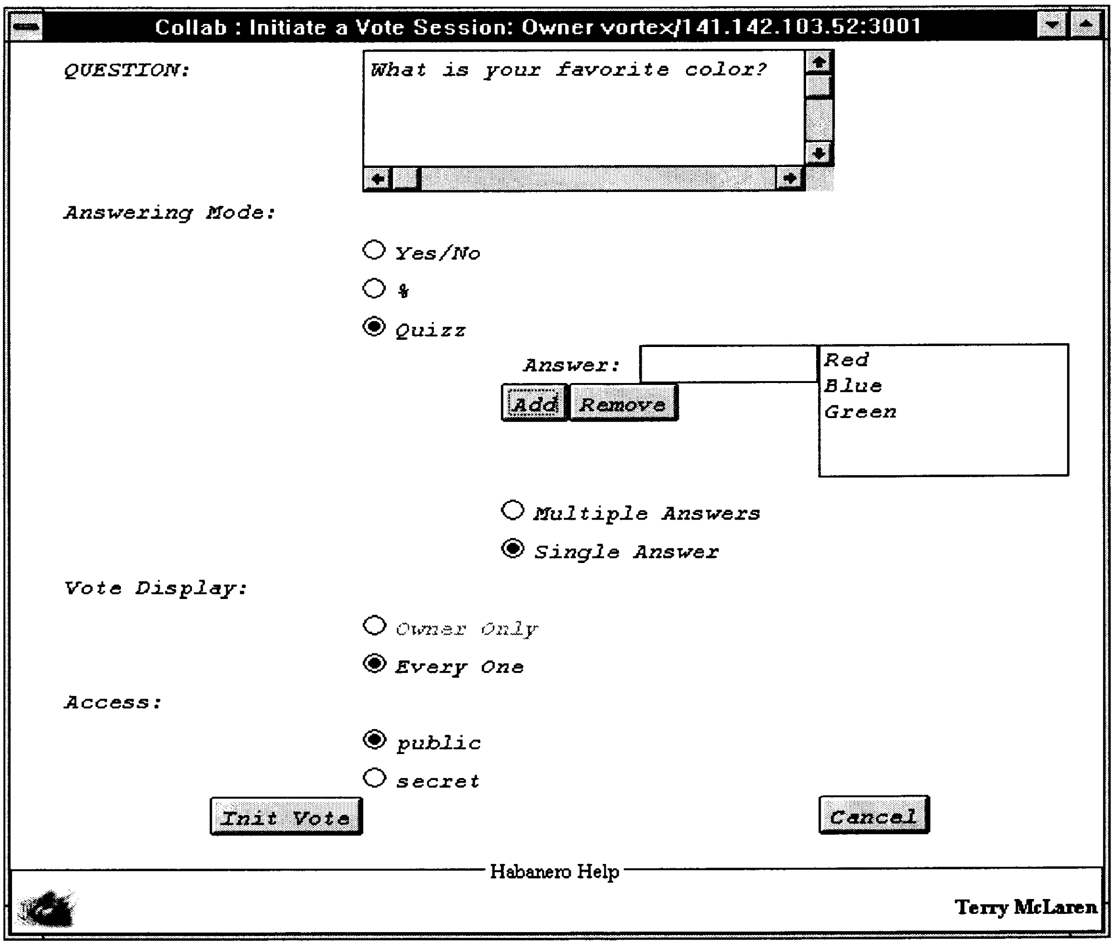
Below are some voting screenshots of GroupSystems (URL: http://www.ventana-east.com/voscreen.htm. Retrieved 06/2001.) Screenshots of GroupSystems WebDemo (URL: http://www.ventana-east.com/webdemo/webdemo.htm. Retrieved 06/2001.) could also be found.


Vote Screen - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Forward Stop Refresh Home Search Favorites History Mail Print Edit Discuss Real.com
Address http://www.ventana-east.com/voscreen.htm
Sample Voting Screens
File Folders Edit Vote Group Options Window Help
Agenda People Whiteboard Handouts Opinion Reports
Agree/Disagree (5-Point)
Strongly Agree (SA), Agree (A), Neutral (N), Disagree (D), Strongly Disagree (SD)
SA A N D SD
1. Automatically darkening windows
2. Anti-lock Brakes
3. Alternate fuel source
4. Automatic air-bags in all directions
Agree/Disagree (5-point) allows participants to indicate the extent of their agreement with each stament on the list, based upon a 5-point rating scale.
10-Point Scale
1 10
1. Automatically darkening windows
2. Anti-lock Brakes
Done
Internet

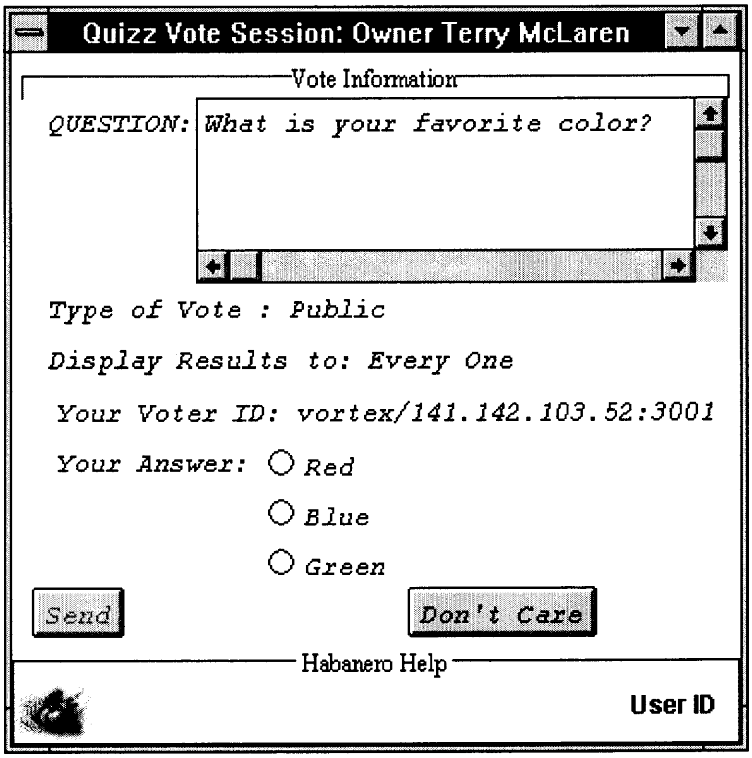

Back Forward Stop Refresh Home Search Favorites History Mail Print Edit Discuss Real.com
ddress http://www.ventana-east.com/voscreen.htm
10-Point Scale
1 10
1. Automatically darkening windows
2. Anti-lock Brakes
3. Alternate fuel source
4. Automatic air-bags in all directions
0-Point Scale allows participants to rate each item on the list, based on an integer scale from one to ten.
Agenda People Whiteboard Handouts Opinion Reports
Yes/No
Y N
1. Automatically darkening windows
2. Anti-lock Brakes
3. Alternate fuel source
4. Automatic air-bags in all directions
es/No presents a list in which each item is a question with a possible response of "Yes" or "No."
Done
Internet



NCSA Habanero Voting Tool (URL: http://havefun.ncsa.uiuc.edu/habanero/Tools/VotingTool/index.html. Retrieved 06/2001.) This Voting Tool is a cooperative vs. collaborative tool. The initiator of the vote defines the question, the answer mode (yes/no, %, multiple choice), the choices when necessary, and if the result information is anonymous. Once a vote is defined, the group receives a vote window. After the vote is complete each member receives a result window displaying the vote count. Voters' vote information is not distributed to the other participants. Instead, the vote information is sent to and tabulated by an Arbitrator running on the Session Server. Below is the main screen of the voting tool:

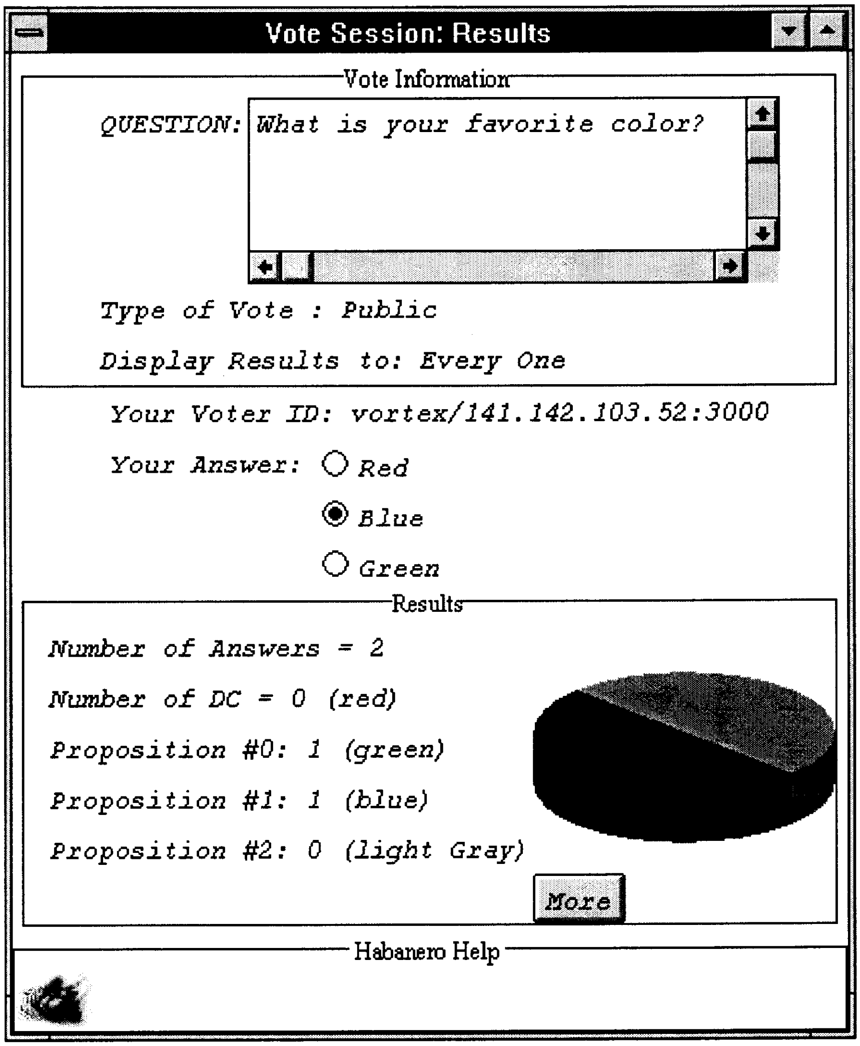


After a vote is defined, each member of a collaborative session receives a Voting Window. This window defines who initiated the vote, the question, the type of vote, where the results get published, the voter ID and the response options. There are four possible response options. Three of the response types (slide bar, checkboxes, radio buttons) are defined by the vote initiator, and the fourth response, “Don’t Care”, returns a blank ballot. After one selects a response, clicking the *Send* button submits his or her response.



After all the ballots have returned to the Session Server or the voting session has timed-out, the Arbitrator calculates and returns the result of the vote. The vote initiator determines whether or not the vote result is publicly displayed. If the "Vote Display" is defined as "Everyone" then the Voting Results window will appear on everyone's machine. If it is defined "Owner Only" then the results only appear on the initiator's system.

The Vote Results window is an extension of the Voting window with the addition of statistical information regarding the vote. The response type determines the type of statistical data.



The "More" button is active only if the vote initiator selected "public" as the "Access" option. When "More" is active one can click the button to display how everyone voted. If "secret" is selected then the button is grayed out and the vote remains anonymous.

Closing the voting window can be initiated by anyone by selecting "Close" button from the system menu at the top left corner of the Results window. However, if someone closes his or her window, all Voting windows will close.

3.2.2 Summary of Web-based Voting Tool Implementations

Voting tools accessible from the Web sampled above contain the following encouraging features:

1. *Voting Methods*. These voting tools cover the simplest "yes/no" voting to very complex voting processes that support Plurality Voting, STV, and Condorcet's Method, etc. The different methods are compared or used complementarily in the voting process.
2. *Scaling Methods*. The scaling methods appearing in these tools include "yes/no", nominal scale, five-point Likert scale, ten-point semantic differential, ratio, and percentage (%) scale. There is one tool supporting the rank order method. No pair-wise comparison was found in these tools.
3. *Interface*. Some tools present the voting items in a very clear way. Using a slide bar on interval scale items is a nice alternative to N-point scaling. There are also some good features in the way to present the voting result, such as using tables, pie charts etc.
4. *Design Issues*. The design of voting tools in a group process has been discussed in depth in several web sites. Issues included the system architecture, the voting process, etc. These discussions would be very useful references for the web-based voting tool design.

However, from the discussions above, problems are also found that exist in both research papers concerning voting tool implementations and current Web-based voting tools. Compared to the rich features of voting theory and scaling methods, current voting implementation is still at the very beginning stage. Not one tool has successfully integrated all the scaling methods, and multiple alternative voting methods into one toolkit. Further more, although voting tools have been identified as a key tool to facilitate group process in expressing preferences, exposing differences and enhancing consensus, no research has systematically discussed the interaction of voting tools and group process, especially Internet voting tools.

3.3 Potentials and Problems of Internet Voting

An Internet voting system is defined as one that transmits untabulated ballot images or ballot data through the Internet. Besides supporting government-related elections, Internet voting systems have been implemented into many kinds of systems. As the literature presented above illustrated, in systems such as groupware systems, group decision support systems (GDSS), and electronic meeting systems (EMS), a voting tool has been identified as a high level tool, and required to be integrated into these systems as an indispensable part. Some other systems that contain the component of preference choice, like knowledge discovery systems, recommender systems, or Internet traffic control algorithms, also actively integrated voting systems as a useful part.

The potentials of voting systems are unlimited. This research will concentrate on its applications in GDSS to support group decision-making powered by Internet technology. Instead of requiring people to vote by traditional paper and pen, or cast votes on various organizational issues at the same time, same place, Internet voting systems would let them cast votes via the Internet at any time, any where. In this section, potentials and problems of Internet voting tools are discussed.

3.3.1 Potentials of Internet Voting

So far, Internet voting is only reported in government-related elections. No research was found on GDSS research using Internet voting. However, there are many on-line surveys and software packages that allow voting via Internet. The benefits of Internet voting are its apparent convenience, 24-hour availability over several days, and the ability of Internet voting to be unaffected by traffic and weather issues (Hoffman, 2000). Other benefits may include the potential cost savings in the long run.

For example, in Alaska in January 2000, 35 people voted via the Internet in the Alaskan Republican Party's presidential straw poll using a password mailed to them in advance. Kathleen Dalton, a member of the Alaska Republican Straw Poll Committee said, "Internet voting opens up a completely new domain to an Alaskan population that is handicapped by vast distances, lack of land transportation routes, and slow or interrupted postal service in winter months".

For distributed groups, such as global organizations, international academic associations, Internet voting would also benefit their decision making in this sense. For example, this could be the scenario: the Association of ACM is going to elect a new executive chairperson. Members of ACM then decide to vote on a group of candidates proposed by the current chair. By using Internet voting tools, all members around the world could cast their votes in a certain period without gathering at one place. Before that, they may also use the voting system to propose their opinions upon the candidates, or initiate new discussion topics, etc. After voting on the Web, members could see the result and their own votes, and may possibly change their votes before the final deadline approaches. To provide a fair voting, the system may have several alternative voting methods to choose from at the beginning, or calculate the result using several methods and have a comparison upon these alternative methods.

3.3.2 Problems of Internet Voting

It has been widely acknowledged that these are the main problems of Internet voting: the identification of users, the security and the reliability of the voting system, the accessibility of Internet, privacy issues, and voter training.

Lance J.Hoffman (2000) reported a case for Internet voting. The Arizona Democratic Party was planning to offer Internet voting in its March 2000 binding presidential primary. Security in this election appeared also to rely on voters signing a form, mailing it in, and receiving by return mail a password that allows them to vote any time within a four-day period. A firm competing with the one running the election for the party declined to make a bid for the election. They were concerned that party officials insisted on allowing people to vote from home, and urged instead voting only at polling stations, so poll workers could guarantee the identity of voters before letting them cast votes. They also worried that the computers used might harbor viruses or other Trojan horse programs. The Voting Integrity project has filed suit in federal court against the Arizona plan, saying it discriminates against minority voters, noting that only half of the households in the United States had Internet access at that time. The League of Women Voters has raised this issue also.

Opponents view with alarm the potential vulnerabilities of Internet voting. Hans Von Spakovsky of the Voting Integrity Project said, “An Internet election is going to be a natural target for hackers.” Governors Gray Davis (of California) and George Pataki (of New York) have noted that the security in Internet voting systems must be greater than that in e-Commerce systems that internalize the costs of a relatively minor amount of fraud. Internet voting systems must have security and integrity at a higher level to insure that votes are not stolen and to maintain public confidence.

In addition to the usual concerns about the privacy of the vote choice, one can foresee other issues being raised. Suppose a voting system provider proposed to offer impartially running an entire election and to bear all the expenses in return for being able to have privileges to market to voters. Should such a proposal be considered? Should this be the case, would the voter be able to, or required to have the choice of in or out of the voting? Is it a good idea to have outsourced voting? What if the voting service provider is based in a different country than the country of the voting?

The main feature of an Internet Voting Tool is that it supports free participation. However, there are pros and cons about this. If properly motivated, one can expect to see a good sample set picked through the Web, leading to satisfying results. However, active participation will require time, energy, commitment, and, most of all, the belief that the participation is likely to have some beneficial outcome. Given the fact that in the 2000 national election, nearly half of U.S. citizens failed to vote, as they believe they have little to gain or lose in the outcome (H. Berghel, 1996), one can never overlook the motivation of active participation. However, since the cost of online participation is low, plus the ease of use, some optimistic outcome can still be expected.

A number of other issues have also been raised. What additional training for Internet voters is desirable? Does Internet voting provide (too much of) an advantage for a well-organized fringe group? Can technology, through Internet voting or some other process, energize voters and reconnect them to the process?

Any voting tools must be based on some rational rules and criteria, and have to provide means to double check if the criteria have been met. However, due to Arrow's paradox, one shouldn't expect that all the criteria are to be satisfied in many voting processes. So one has to be very cautious in applying these rules and criteria in the voting toolkit. Moreover, due to the complexity of the various voting methods, especially vulnerability to manipulation, user training is definitely required before using any of these methods. The objective is to let users understand how the voting process goes, what the result means, what potential problems this process and result could have, how to manipulate on it, and how to look into other methods as complements.

As to the question of how Internet voting affects group process, that is what this research is going to look into in the controlled experiment.

CHAPTER 4

DYNAMIC VOTING

It is believed that the use of voting tools can enhance the group process in a positive way, that is, help uncovering the patterns of consensus among group members; encourage group thinking; and enhance the exploration of a problem at a deeper level. Electronic voting can facilitate decision-making that is too painful using traditional paper and pencil methods. Furthermore, by using anonymous voting, issues that were buried during normal conversation could be brought up; process losses can be reduced to some extent. However, currently in GDSS study, voting is often viewed as the concluding step in the group process, not as a potential instrument for measuring the progress of the group in the examination of their problem, promoting understanding to eliminate ambiguities, fostering exploration and guiding the group process. Few researches in the past illustrated the relationship among the use of voting tools, voting procedures, and decision outcomes (e.g., quality and satisfaction), and none of the research on GDSS takes the voting procedure dynamically.

In this research, instead of applying traditional one-time voting, the author proposed to improve the group process by providing a feedback mechanism on group voting across the whole group process, that is, using dynamic voting model to improve the group process. Furthermore, it is going to be combined with Internet technology. The future of Internet voting is dynamic feedback to the voters! Powered by Internet technology, the Dynamic Voting Tool builds the voting tools on the Web, so that users could access it at any time, anywhere via the Internet. In this chapter, the ideas of human dynamic voting will be presented.

There are two different kinds of Dynamic Voting, one is Computer Dynamic Voting (CDV), and the other is Human Dynamic Voting (HDV). They have very different meanings and application areas. To better understand the Human Dynamic Voting, which is implemented in the Dynamic Voting Tool, computer dynamic voting is first examined.

4.1 Computer Dynamic Voting

The concept of computer dynamic voting was initially created to deal with distributed file management in computer networks. "Dynamic Voting was created to allow files to have the same availability as in available copies, and yet to perform correctly in the case of network partitions." (Davcev et al., 1985) The author calls this concept of dynamic voting "Computer Dynamic Voting (CDV)" from this point on to distinguish it from "Human Dynamic Voting (HDV)" which will be defined and discussed later in this chapter.

Computer Dynamic Voting is said to provide the highest availability in partitionable networks. To explain it briefly, in computer dynamic voting, many copies of the current version of the file are distributed in a set of nodes in the network. When all nodes in the network are up, users can read the file from any of the current nodes, however, any file updates must be written to all nodes at the same time. In order to maintain consistency during network partitions, if a node sees half (or more) of the previously accessible replicate nodes suddenly become inaccessible, it assumes that they have been partitioned away, and prevents further access. Computer dynamic voting therefore allows a file to be accessed as long as there are no halving-partitions (where exactly half of the replicas are on each side of a partition).

There are many other variations of computer dynamic voting. For example, In Linear Dynamic Voting (Jajodia, 1987), replicas are rank ordered to allow a single partition to access the file in the case of a halving-partition. During a halving-partition, only the partition with the highest rank is allowed to continue accessing the file. Linear Dynamic Voting allows a file to be available whenever two copies are accessible, and half of the time when a single copy is available.

Computer Dynamic Voting has proven to be the most available example for maintaining quorums in unreliable networks. However, many of the suggested protocols may lead to inconsistencies in case of failures. Other protocols severely limit the availability in case failures occur during the protocol. Many research efforts have been made to improve the dynamic voting algorithm. For example, Danny Dolev et al. (1997) presented a robust and efficient computer dynamic voting protocol for unreliable asynchronous networks which allows the system to make progress in cases of repetitive failures.

Although Computer Dynamic Voting adopted voting techniques, the essence of it is nothing but a set of algorithms operated by the computer networks automatically. However, when one adopts dynamic voting into group decision-making process, humans are an active part of the process, they should be able to interact with the voting systems. So one would expect to see different scenarios in such situations. For this reason, in the following descriptions, the author will use "Human Dynamic Voting" rather than "dynamic voting" to refer to the dynamic voting in group decision support system (GDSS) settings.

4.2 Human Dynamic Voting

The concept of Human Dynamic Voting (HDV) has existed for decades, although it may not be explicitly defined and addressed this way.

A Group Decision Support System (GDSS) has been defined as an interactive computer-based system that facilitates solution of problems by a group of decision makers (DeSanctis, et al., 1985). GDSSs have also been described as "the latest advance in a long series of social technologies for groups" which includes Robert's Rules of Order, Nominal Group Technique, and the Delphi Method (DeSanctis & Poole, 1987).

With the Delphi technique, communication structures are designed to allow knowledgeable individuals to efficiently pool or compare information on complex problems (Linstone & Turoff, 1975). The technique is traditionally implemented with pen and paper over several rounds. Analysis and feedback are provided to the respondents between rounds, allowing them to expand and/or change their original views.

Hiltz and Turoff (1985) believed that a large number of users could exchange information in a more concise and precise way when numerical responses were used in place of conventional text responses. The computer could be used to average, analyze, and display results for a given issue. They called the idea "polling not to elect or to sample but to facilitate participation." Furthermore, they proposed that such procedures could take the form of scales that indicate, for instance, the degrees of agreement on a statement or proposal on a one-to-five or one-to-ten scale, numerical estimates of items such as the proportion of a budget to be devoted to research and development or advertising, or the rank ordering or alternatives.

Hiltz and Turoff (1985) reported a system developed for a standards group on EIES (i.e. Electronic Information Exchange System, developed by NJIT during the late 70s and early 80s under the direction of Murray Turoff and Starr Roxanne Hiltz) to allow individuals to propose an alternative definition (standard) for a phrase. EIES provided some nine different Delphi-like voting scales that could be attached to conference comments. For example, an individual proposing a project modification could attach voting scales for "desirability" and "feasibility". The computer would then collect the votes and provide a display of the resulting distribution. A proposed standard would be issued only if the agreement was unanimous. They found that this rather simple software modification speeded up the group's work considerably by keeping members up-to-date on the relative acceptance of all the proposed alternatives.

As in any Delphi-like voting process, voters could change their votes at any time. The voting process and the associated structures for relating complex information devised in Delphi designs represent a highly condensed form of human communication allowing extremely efficient transmission of a great deal of information. It is the merger of these techniques into CMCS structures that will allow geographically dispersed groups to work as teams dealing with complex problems on a day-to-day basis, and this is a highly efficient way of discovering if the group already agrees with a proposal and avoiding what may be a lot of unnecessary communication. Considering a series of items in this manner allows groups to make a quick determination of the issues on which they need to focus discussion. This multi-round of idea-generation, evaluation, voting, feedback and modification/re-evaluation process is actually a process of Human Dynamic Voting.

Early CMC research also reported the effects of Human Dynamic Voting. In the early 80s, Hiltz, Turoff and others introduced the concept of "computer support for group versus individual decisions" and launched a series of three experiments to explore the process and outcomes of group decision-making within a computer conferencing environment (1980, 1982, 1986, 1989). In their second experiment, versions of a computerized conferencing software environment were created that included programs for the formal selection of a designated leader and for the statistical summarization and feedback of group members' opinions. Support for the use of statistical or summarized feedback of opinion-oriented data as a mechanism to aid decisions also comes from the Delphi Method.

Twenty-four groups of five professionals and managers used computer conferences to reach agreement on the best solution to a complex ranking problem. Two software tools for structuring the conferences were employed in a two-by-two factorial design. Groups with "Designated Leadership" (DL) used software support to elect a discussion leader. Groups with "Statistical Feedback" (SF) were presented with tables periodically that displayed the mean rank and the degree of consensus for each item (Hiltz et al., 1991). All groups entered their ranks on the computer and received a simple list of the members' rankings of the items. In the "Statistical Feedback" (SF) condition, a second table was generated. This listed the items in order of their mean ranking by all group members, indicated the ranking of each item by each group member, and reported two measures of the amount of agreement so that the group could follow its progress toward consensus.

Hiltz et al. (1991) argued that the use of numerical information through quantification and display of judgments and opinions was generally thought to lead to higher quality and/or faster decisions. Statistical feedback, especially when it is not anonymous, may initially highlight disagreement in the group. They also argued that it is reasonable to speculate that the first step for reaching agreement is to see the nature of the disagreement clearly. Therefore, they hypothesized that Statistical Feedback (SF) could help to integrate the group's communication by creating a composite picture of its collective decision at any point in time, and by focusing attention on items generating the most disagreement, thus suggesting a path to the solution of the problem. Unlike many people's vision of using scaling methods to fit presetting scales, measuring behavior or describing data structure as been discussed in chapter 2, here scaling methods (including the feedback) were employed to expose the disagreement among group members' opinions. Voting procedures were also employed to enhance this process.

The experimental results showed that a Designated Leader (DL) improved levels of consensus; in the absence of a leader, SF improved level of agreement slightly. Statistical feedback as operationalized in this experiment was detrimental to the ability of a group to achieve "collective intelligence," defined as a group decision better than the pre-discussion decision of any of its individual members.

In this experiment, all groups were given the condition of dynamic voting, since all groups were allowed to vote at any time, and change their votes freely; they were all allowed to get the feedback of group rankings. However, the experiment was not initially designed to look at the effect of dynamic voting, but leadership and feedback process. Since the dynamic voting condition was primarily confounded with other conditions (leadership vs. statistical feedback), it was hard to tell from the experiment result how dynamic voting alone affected group decision-making, such as quality of decision, group equity, group consensus, and subject satisfaction. The author strongly feels that more theoretical and empirical research needs to be employed to explore this issue.

In this research, Human Dynamic Voting (HDV) is defined as the voting process that incorporates the use of scaling methods, voting schemes (i.e. voting methods), and dynamic voting procedures in a freely interacting group. "Dynamic" means that the voting is not done just once per person, but can be allowed to carry out freely for many times during certain time slot, until certain preset criteria are met, such as deadlines, times of repeated votes, or number/percentage of total votes. Unlike Computer Dynamic Voting, in Human Dynamic Voting, the voting procedure is defined by a set of voting protocols that tells how the interactive voting process is running, such as, how to control user identification other than anonymous voting, how to store per-user-based voting information, how to coordinate the system when multiple users cast their votes simultaneously, how to provide feedback information to each user (what, when and how to present the voting results to each user,), and how to allow users to manipulate their votes locally before further votes are submitted, etc.

Human Dynamic Voting has certain unique features that are different from the classical one time voting. A Human Dynamic Voting tool is not supposed to be used to signify the end of the decision process, but used during the group process to uncover the patterns of group consensus, or in case of conflicts, to discover the lack of consensus, and to enable the group to explore the issue at a deeper level. It should serve to measure the current status of the group and the individuals creating that status in a dynamic process.

Two forms of feedback are provided to individuals in Human Dynamic Voting: outcome feedback (the result of voting), and cognitive feedback (that is, feedback on the underlying pattern of judgment, or judgment policy). The outcome can also carry two forms: group outcome and individual outcomes. It also permits freely on-line discussion using comments or forums between voting activities. And in so doing, it is supposed that better understanding of other people's opinions within the group could stimulate more sincere thinking and improve group judgment. Since the dynamic voting tool can be accessed on the Web freely at any time, it may also reduce the process loss of time pressure.

The classical classification of scales and their objectives does not fully explain the use of scales in the context of Human Dynamic Voting. In this context, the objectives of scaling are to:

- Aid the voters to eliminate biases and miscommunications
- Provide a group understanding of the position of the group and the positive individual relations to it
- Expose underlying factors influencing the voting
- Encourage improvement in the voting results via appropriate dynamic feedback.

Human Dynamic Voting is a response-centered approach. The objective is to make clear what are the subject responses and what are the stimuli to the voters. As a result, scaling methods are heuristic methods that must be evaluated in HDV.

It has been claimed that the judgments of interacting groups are more accurate than those of average individual members, but are not as accurate as they "should" be. This view led to two crucial implications:

- Groups offer the possibility of more accurate judgments than single individuals, especially on tasks with considerable complexity or "intentional depth".
- Freely interacting groups do not live up to their potential – that is, they do not equal or exceed their best member – and that deficiency reflects process losses.

Various investigators set out both to explore where and how such process losses come about in freely interacting groups, and to develop ways to make group judgment better by avoiding these process losses. Two forms, in particular, were developed to study and try to improve accuracy of group judgments: the Delphi Technique and the Nominal Group Technique.

The Delphi Method simply feeds back individual judgments, anonymously, with a second and perhaps third round of judgments following feedback without any interaction. In one well designed study (Rohrbaugh, 1979), although the Delphi Method did better than an average pretest individual's judgment, it did not do better than the second best individual judgment, and it did distinctly worse than the best member's judgments.

The Nominal Group Technique is also a "voting" technique, but feedback is done publicly by having individuals announce their answers in turn; and this is followed by limited interaction – to explain and clarify judgments – before the subsequent group decision (obtained by majority vote or averaging). While this may give the individual member more of a feeling of involvement with the other people than does the Delphi method, it also clearly invites the operation of group influence processes even more than the Delphi Method.

Human Dynamic Voting can be viewed as the extension of Delphi Method and Nominal Group Technique, in the sense that it provides feedback to individuals freely during the whole process, and allows changes of mind as did in Delphi at any point, and this change can be perceived by other group members immediately. The feature of free comments will give individuals more opportunity to express themselves, interchange ideas, expose disagreement, or seek compromises. Individuals should be allowed to do voting or comments anonymously as an option. This feature of free interaction should reduce the process losses the Delphi Method or Nominal Group Technique may have, and foster the accuracy of group judgment.

4.3 Hypotheses with HDV Tool

In this research, the author has designed and developed a Web-based Dynamic Voting Tool, which not only implemented key Human Dynamic Voting features in the toolkit, but also integrated several common voting and scaling methods, and could be accessed via Internet. The details of the tool will be discussed in the next chapter.

Overall, given all the discussions in the previous sections in this chapter, it is hypothesized that such a toolkit will positively influence group process with higher quality of decision-making, higher perceived satisfaction, more process gains and less process losses, and higher level of conflicts/consensus exposure. Several general hypotheses can be formed with the support of the Web-based Dynamic Voting Tool:

1. *Quality of Decision-making*: Groups with HDV tool support will have higher quality of decision-making than groups without HDV tool support.

2. *Perceived Satisfaction*: Groups with HDV tool support will be more satisfied with their decision-making (solution/process) than groups without HDV tool support.

3. *Process Gains/Losses*: Groups with HDV tool support will have more process gains and less process losses than groups without HDV tool support.

4. *Conflicts/Consensus level*: Groups with HDV tool support will yield higher level of conflicts/consensus than groups without HDV tool support.

These hypotheses will be further deliberated in the following chapters and will be tested in a controlled experiment. And some of the results will be reported in this dissertation.

CHAPTER 5

FEATURES OF THE DYNAMIC VOTING TOOL

The Dynamic Voting Tool is a Web-based collaborative tool. It can either be combined with the List Gathering Tool (developed by Yuanqiong Wang) to form the SDSS Toolkit, or just run as a stand-alone version to support voting activities. Features of the Dynamic Voting Tool that have been implemented in the collaborative SDSS Toolkit are discussed in this chapter. New features that need to be improved or integrated into the Dynamic Voting Tool in the future are also discussed based on user feedback during the controlled experiment and the field studies.

Before discussing the Dynamic Voting Tool, a brief description of the SDSS Toolkit is introduced in the next section.

5.1 SDSS Toolkit

A Social Decision Support System (SDSS) is a type of inquiry system that supports the investigation of complex topics by large groups that hold many diverse and opposing views (Turoff, et al., 2002). The web-based collaborative SDSS Toolkit includes two parts: a List Gathering Tool and a Dynamic Voting Tool. The objective of developing such a toolkit is to help the individuals in the group to effectively produce, integrate, and synthesize their diverse views asynchronously. The SDSS Toolkit has many features to enhance the group process:

- All participants can come to respect and understand the differences caused by diverse values and interests of the contributing population. All group members can create/edit their own root items to express their ideas. Modifications can be added and voted on by other members to offer better wording. Allowing the addition of pro, con and neutral comments about each item before and during the voting process to encourage re-examination of positions and possible vote changes by the participants.

- There can be a movement towards consensus on at least some of the issues involved. Focused group discussions are encouraged by presenting the detailed vote distributions so that the participants can determine which items have polarized and uncertain voting patterns, and which items have higher degree of consensus.
- There is limited need for human facilitation of the meta-process of communication which is replaced by dynamic voting processes. Group members can change their mind and vote many times after viewing other members' voting results or comments. When there is large disagreement on the list items, or the pro/con/neutral comments reflect major changes to be made on the voting items, then the list of root items is modified, and a new round of voting can be granted by the group manager (facilitator).

The architecture of the SDSS Toolkit is shown in Figure 5.1 below.

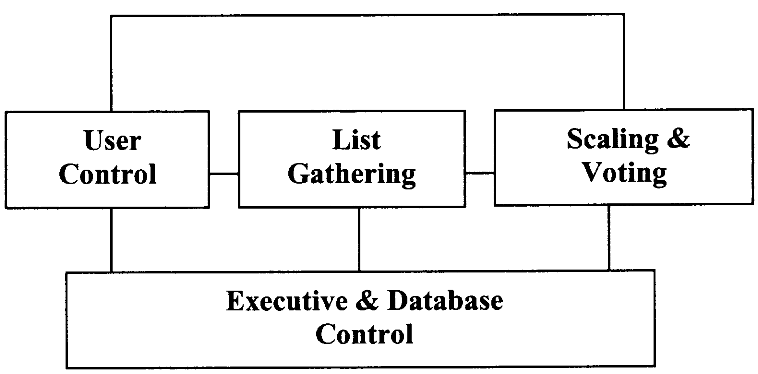


Figure 5.1 SDSS toolkit architecture.

The SDSS Toolkit has four main modules: User Control, List Gathering, Scaling & Voting, and Executive & Database Control. The User Control module deals with user registration, password control, and user role management. The List Gathering module deals with gathering and manipulating a list of items/criteria concerning some specific issues. The Scaling & Voting module provides scaling methods such as "yes/no", five-point Likert scale, seven-point semantic differential and rank order rating. It also deals with voting and calculating (with different schema) on the lists of items that have been created with the List Gathering Tool. The Executive & Database Control module performs database control and stores and processes operations on the central database in the server side.

The Dynamic Voting Tool is not a simple tool that just provides majority voting or simple ranking, but integrates several common voting and scaling methods. It supports "yes/no", rank order, Likert scales, semantic differential scaling methods, and different voting methods such as plurality voting and approval voting. The major feature of the Dynamic Voting Tool is to provide Human Dynamic Voting. That is, during a group process, group users can change their minds and change their votes repeatedly until specified criteria are met.

As a fundamental part of the SDSS toolkit, the List Gathering Tool helps group members to organize their ideas into a manageable list with clear structure. Group members can collaboratively build a list and organize the discussion as items in the list. Instead of using a simple post and reply structure in the general conferencing system, a contribution can be not only the users' original thoughts on a discussion topic, but also a suggested replacement for a number of other items on the list (e.g. consolidation), or a comment on an existing idea. Figure 5.2 below shows the process of the List Gathering Tool.

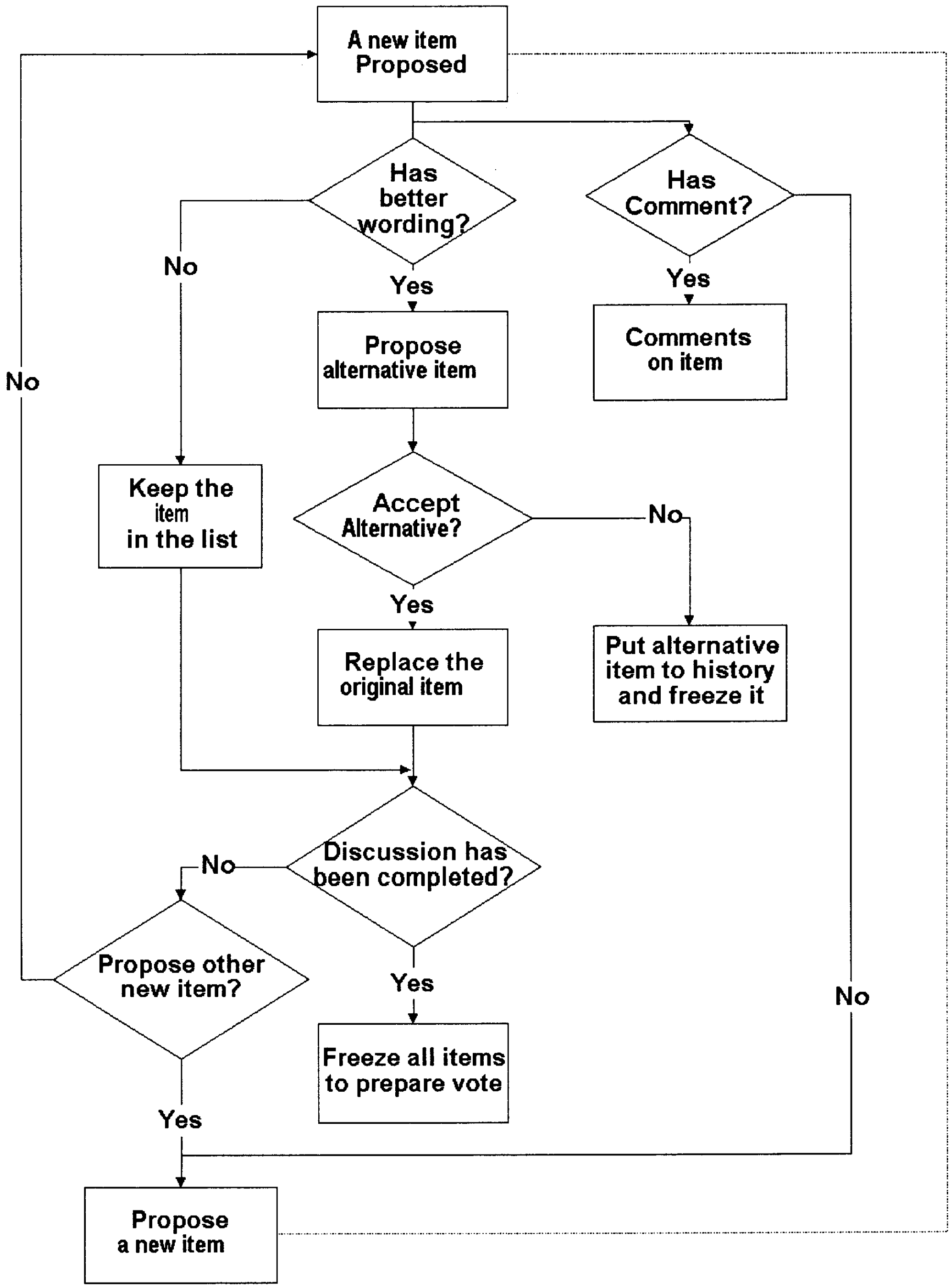


Figure 5.2 List Gathering Tool process model.

Overall, the SDSS system includes the following major functions:

- Allow users to collect problems for decision-making, set up and manage routines (i.e., topics/lists) for collecting criteria items concerning the problems, including establishing the problem-solving group, nominating member roles, gathering criteria lists, and edit criteria lists, etc.
- In a network environment, users can access the SDSS Toolkit freely at any time, any place through a Web-browser and may vote on the criteria items. Users are required to authenticate themselves (*Anonymous* is always a choice). They can also modify their individual voting results at any time according to the rules.
- Voting results will be processed dynamically under certain conditions using voting rules like total/percentage of votes, mean/average, or "Thurstone's Law of Comparative Judgment". Voters can check the voting results (including the voting history) online at any time. The resulting discussion feedback may be used to encourage vote changes to take place at any time.
- While the list is frozen during most forms of voting, the participants may continue to contribute to the discussion about the items by adding pro/con/neutral comments.

The SDSS Toolkit is developed using ColdFusion5, a powerful web application server, and the database system in use is MS Access. The development of the toolkit is highly collaborative between Yuanqiong Wang, the developer of the List Gathering Tool, and Zheng Li, the developer of the Dynamic Voting Tool. While independently working on the above two modules, they worked closely together on the two common modules – User Control and Executive & Database Control.

In this dissertation, the author focuses only on the Dynamic Voting Tool, i.e., the design and implementation of the scaling and voting module, as well as related database operations. User Control is a very important common module that has been implemented in the SDSS Toolkit as well as a stand-alone version of the Dynamic Voting Tool. However, in the stand-alone version of the Dynamic Voting Tool, the List Gathering module has been implemented only in a very simple way to support the collecting and editing of topic/list/items. The purpose of developing such a stand-alone version is not only for the experiment purpose (to have a voting-tool-only condition), but to support voting-only activities which may have practical value.

In the following sections, features of the Dynamic Voting Tool are discussed; results from a System Survey after the controlled experiment are analyzed; and future improvements based on the analysis and observations are also suggested.

5.2 User Role Management

In the Dynamic Voting Tool stand-alone version, the following six types of user roles are supported: Admin, manager, member, voter, observer, and guest. The functions of each role are displayed in Table 5.1 below.

Table 5.1 User Roles in Dynamic Voting Tool

Role	Function
Admin	The system administrator can do the following tasks: • Manage topics, including create topics, assigning topic manager/member/voter roles, and edit and delete topics. • Manage users, including delete or change user profile, and assigning user roles. • All operations on list and list items, including open/freeze/close a list, grant/drop a vote session, create/edit/delete operation on all lists and items. • Voting on all lists that are granted for voting. • Checking voting results on all lists, including checking the voting raw data and the comments on all votes.
Manager	The topic manager can do the following tasks: • Manage topic member's role -- assign topic manager. • Create a new list or a new item within the topic. • Edit/delete lists/items posted by other members. • Open/Freeze/Close a list or Freeze/Unfreeze an item • Grant/drop a vote session on a frozen list. • Voting on all lists that are granted for voting. • Checking voting results on all lists, including checking the comments on all votes.
Member	A topic member can do the following tasks: • Create a new list or a new item within the topic. • Edit/delete lists/items created by himself/herself only. • Read all other members' posts within the topic. • Voting on all lists that are granted for voting. • Checking results on all lists, including checking the comments on all votes.
Voter	A topic voter can do the following tasks: • Read all topic members' posts. • Voting on all lists that are granted for voting. • Checking results on all lists, including check the raw data and the comments on all votes.
Observer	The observer role is assigned by the administrator only. A observer can not vote on any lists, but can do the following tasks: • View all the lists/items within all the PRIVATE and PUBLIC topics in the system. • Checking results on all lists, including checking the comments on all votes.
Guest	Guest is the default role when a new user profile is created. A guest can not vote on any lists that are granted for voting, but can do the following tasks: • View all the voting lists and items within all the PUBLIC topics in the system. • Checking results on all Voting lists, including checking the comments on all votes.

5.3 Scaling and Voting Design

In the SDSS Toolkit, the main concerns of the design of the Scaling & Voting module included the following issues:

- What scaling methods shall be chosen for specific voting items and how to present them?
- How to choose the voting methods (e.g., initiators/system decide, or users have the freedom to choose)?
- How to present the items to users in a clear, but unbiased way (e.g., randomly, reverse order)?
- How to provide user awareness before voting (e.g., mark as "new", or email notification)?
- How to provide user confirmation after voting (e.g., display the voting choice for user confirmation before submitting it)?
- How to store user voting information (e.g., history of voting), and how to process voting data (e.g., use which method, synchronization of the data etc.)?
- How to present the results to users during and after the voting process (e.g., pies, bar charts, data tables, raw data etc.)?

Since some of these issues are highly scaling/voting methods dependent, the system implementation takes great caution on these issues. Besides, there are some other general considerations on the design as discussed below.

5.3.1 Scaling Design

There are sets of scaling methods that could be used for voting routines. Five widely used scaling routines were implemented in the Dynamic Voting Tool.

Yes/No Vote: It features three categorical answers: "Yes", "No" or "No Judgment". Voters can select "Yes" or "No" or "No Judgment" to a statement. During a Yes/No voting process, the result will show the number or percentage of "Yes/No/No Judgment" votes, and the total number of votes submitted. Users can also sort the results based on one of the above categories and view the results in a data table or graphically (Bar/Pie/Line, etc.) accordingly.

Categorical Vote: It features six categorical answers, such as "Critical Factor", "Very Important", "Important", "Slightly Important", "Unimportant", or "No Judgment". Voters can select one of these categories to a statement. During a categorical voting process, the result will show the number or percentage of the six categorical votes, and the total number of votes submitted. Users can also sort the results based on one of the above categories and view the results in a data table or graphically (Bar/Pie/Line, etc.) accordingly.

Rank Order Vote: Given a set of comparable alternatives or a list of items, voters can rank order these alternatives/items. For example, if there are five alternatives A, B, C, D, and E in a list, each individual in the group can rank order these five items. Individual 1 may rank order them from No.1 to No.5 as following: [C, E, A, D, B]. That is, item C as rank 1, item E as rank 2, item A as rank 3, item D as rank 4, and item B as rank 5.

During a rank order voting process, no ties are allowed in the individual ranking, and voters need to vote on all the items. The system will automatically verify this to make sure a voter does so in his or her vote. The result will show the Thurstone's Law result (default), the Borda Count result (Borda, 1781), the Condorcet (Condorcet, 1785) result, and the mean of the ranks. For the meaning of each of these rank order data calculation methods, users can go to the system help file for more details, or they may need some necessary training beforehand in order to understand the meaning and the proper use of each of these methods.

Five-point Likert Scaling: It features five point items to a statement: [Strongly Agree, Agree, Undecided, Disagree, Strongly Disagree]. Voters can choose one item from these categories. During a categorical voting process, the result will show the number or percentage of the votes on each category, and the total number of votes submitted. Users can also sort the results based on one of the above categories and view the results in date table or graphically (Bar/Pie/Line, etc.) accordingly.

Semantic Differential Scaling: It features seven point interval items to some facts (e.g., Useful 1 2 3 4 5 6 7 Useless) and "No Judgment" is always an option. Voters can choose one item from it. During the voting process, the voting result can be counted as the weighted average and standard deviation of the scales, the distributions and the total number of votes submitted, and vote changes, etc. Users can also view the results in date table or graphically (Bar/Pie/Line, etc.) accordingly.

5.3.2 Voting Methods and Results Analysis/Calculation

Based on the different scaling methods that have been used, the Dynamic Voting Tool provides several voting methods. The analysis and calculation of the voting results depends on these methods.

Total/Percentage: In case of nominal scale voting, each voter votes for only one alternative. The total numbers of votes, and the percentage of each alternative are given.

Mean/Average/Standard Deviation: For interval scale voting, each voter votes for only one alternative. The total numbers of votes, the mean/average of the votes, and standard deviation are provided.

Plurality Voting: Given a list of alternative items, each voter votes for only one alternative. The alternative with the most votes wins.

Approval Voting: Given a list of alternative items, each voter can vote for as many alternatives as he/she wishes. The alternative that receives the most votes wins. There is no justification for submitting a vote approving of all alternatives or disapproving of all alternatives.

Borda Count: In the case of rank order voting, each alternative is given a count by assigning points. For N alternatives this is N-1 points for each vote that is ranked 1st, N-2 for 2nd, etc., all the way down to one point for second to last, and zero for the last place. The alternative with the highest count wins.

Condorcet's Law: In the case of rank order voting, the way the votes are tallied is by computing the results of separate pair-wise comparisons between all of the alternatives, and the winner is the one that wins a majority in all of the pair-wise comparisons.

Thurstone's Law of Comparative Judgment: In the case of rank order voting, in some situations, there is a "just noticeable difference" between several comparable alternatives. It is hard to scale the alternatives separately, but they can be compared in an orderly way. Thurstone's law of Comparative Judgment is used in these situations as a scaling tool. The distributions of the judgment when in large times (statistically) can be seen as normal distributions, and one can derive the means and dispersions of each item's distribution, thus get the order of these alternatives. By applying Thurstone's Law of Comparative Judgment (Li, et al., 2000), one can turn the individual rank order results in a group into one single interval scale group results. And by looking at the distance between each individual item (which makes sense theoretically), one can gain better insight into the results.

5.3.3 Dynamic Voting Design

In the Dynamic Voting Tool, the key feature of Human Dynamic Voting is to allow voting on a list of items in several rounds that is defined and controlled by the group manager/administrator. The concept of rounds (or sessions) and how to apply it will be further explained in the next section.

Another key feature of Human Dynamic Voting is to allow users to vote more than once during a voting session. In order to do this, the system can remember the voting history of all voters in its central database. The system remembers the results of each vote and the date/time of the vote. The voter can always check his/her voting history before or after submitting a new vote. The result of the last vote record is presented to the voter when he/she makes a different vote. The system has to determine the policy of how to calculate the final result with the following two options: (1) Only report the group result based on all voters' last valid votes, or (2) Calculate all the votes that have been submitted during the voting session.

The Dynamic Voting Tool also allows comments on the voting issues during voting submission. Users can check the records of these comments at any time to provide insights on why voters made certain votes or why they changed their minds. It is expected that the exposure of such opinions will facilitate understanding among group members during decision-making, especially when dynamic voting occurs.

5.4 System Definition and Description

The key concepts and definitions of the SDSS Toolkit, including the Dynamic Voting Tool, and very brief descriptions on how to use the Dynamic Voting Tool, are presented below.

5.4.1 Concepts and Definitions

Below are the definitions of some critical concepts of the SDSS system.

Topics: Topics are the discourse subjects. For example, "Food", as a topic, can be a discussion subject. One can define the subject in more detail with the description as "to select the favorite food in America".

Lists: Lists are the areas that organize the discussion topic. There can be multiple lists within one topic. For example, the topic "Food" can have "Dessert", "Vegetables", and "Fruits" as its lists.

Root Item: Root items are alternatives listed within each list. A root item is a specific idea or option within one list. For example, in the list "Fruits", there can be several root items such as "apple", "banana", etc.

List Status: Each list can have one of four types of status: "Open", "Frozen", "Closed", or "Granted for vote". Only the system administrator or the topic manager can change a list status.

- If a list status is "Open", topic members can Add/Edit/Delete a root item.

- If a list status is "Frozen", topic members cannot Add/Edit/Delete any root item in the list.
- If a list status is "Closed", topic members cannot do any other operation in the list (including Add/Edit/Delete a root item to the list, or vote on the root items of the list) except check the voting results.
- If a list status is "Granted for vote", the topic manager cannot Open/Freeze/Close the list unless the voting session is stopped. Topic members can only vote on the root items of the list, or check the voting result, but they cannot do any other operations (including Add/Edit/Delete a root item in the list).

Grant a Vote: When a list is ready for a vote, the system administrator or the topic manager can grant a voting session for the list. The following issues MUST be decided when granting a vote:

- Select the voting method
- Define the deadline for this voting session
- Whether or not to allow add comments on the voting list during voting
- Whether or not to allow anonymous voting
- Whether or not to allow topic members to view the raw data on the voting list
- Repetitive voting is allowed in one voting session. When calculating the voting results, calculate only a person's last vote or calculate all the votes?

Stop a Vote: This is the reverse operation of "Grant a Vote". When a list is granted for a vote, in the following cases the voting session needs to be stopped:

- Current voting list and/or its root items need to be modified

- The voting method needs to be changed
- The voting deadline is due
- The vote is completely finished

Only the system administrator or the topic manager can stop a voting session for the list.

Voting Session (or Round): A voting session is also called a "round" in the SDSS Toolkit (and the Dynamic Voting Tool). A voting session (or a round) of a list refers to the voting period from the time a list is granted for voting to the time a list is stopped for voting. A list can have as many voting sessions (i.e., rounds) as necessary during a group decision-making process. To understand this concept, see an example below:

Assume there is a list called "*Task Force*". It has five candidates as root items: *Adam*, *Billy*, *Cathy*, *David*, and *Ellen*. A small group of people will work on the list to

- Select a three-person task force,
- Elect a leader from the selected three persons.

<u>Round 1</u>: First the group needs to pick three persons out of the five candidates. A "Yes/No" vote is granted to the list. This is the starting point of the first voting session (or Round 1). Group members can vote on the list in this round. When all group members have finished their votes, the vote is stopped. That is the end of the first voting session. Based on the "Yes/No" voting result, three candidates who win the most "Yes" votes are selected – For example, *Billy*, *Cathy*, and *Ellen*.

<u>Round 2</u>: However, assume that due to some reason, the root items of the list have to be modified. *Ellen* has to be deleted, and *David* has to be replaced by *Gary*. The group

members have to vote again on the modified list with four root items. A "Yes/No" vote is granted again for the modified list for the second voting session (or Round 2). In this round, the group cannot adopt the voting result from the first round since some of the items have been changed. However, they can still check the voting result in the first round (including the title and descriptions of the list and all root items in the first round) as a reference. When all group members have finished their votes in the second round, the vote is stopped. And that is the end of the second voting session. Based on the voting result of this round, three candidates are picked – *Billy*, *Cathy*, and *Gary*.

Round 3: Now the group needs to elect a leader out of the selected three persons. The list has to be modified again before another vote is granted to the list: "*Adam*" has to be deleted from the list. A "Rank Order" vote is granted to the list for the 3rd Voting session (or Round 3). The group needs to vote again. They are still able to check the voting result in the first and second rounds. When all group members have finished their votes, the vote is stopped. And that is the end of the third voting session. Based on the "Rank Order" voting result of this round, one candidate is picked as the leader – *Cathy*.

In the above example, three voting sessions have been granted to the list "Task Force". Group members can vote as many times as they like during each voting session, and they can view the voting results in the previous voting sessions as well as the current voting session at any time. When applying the Dynamic Voting Tool, depending on the problem solving procedures, one can have as many voting sessions as needed.

Having explained the main concepts of the system, a brief discussion of how to use the Dynamic Voting Tool (or the Scaling & Voting module in the SDSS Toolkit) is presented below.

5.4.2 New User Registration

In the Dynamic Voting Tool, users must register in the system before using it. Here is how to do it.

- Open a Web browser; enter the URL of the Dynamic Voting or Tool; the login page will appear. Click the "New User" button to enter the registration page. Fill out the form to create a new user profile. Users may change their profile later. By default, the new user role is "Guest". "Guest" user is only able to view the voting lists in the "PUBLIC" topics and check the voting results.
- After creating the user account, the system administrator will add the user into the appropriate topic(s), and assign a role within the topic, such as topic manager, member, voter or observer.
- After being added into specific topics, a user can go to the login page, enter the username and password to login to the system. First, the user will see all the topics available to him or her. The topic name, attribute (Private/Public), and the user role within that topic are listed in a table. Users can join the workplace for a topic by clicking the topic name.

5.4.3 Wok With The Dynamic Voting Tool

In the Dynamic Voting Tool, when group members are working together within a topic, these are the procedures they need to follow:

- **Create a list**: Create a list that needs to be voted on. Both topic manager(s) and member(s) can do this.

- **Create root items**: Create root items under the list. Both topic manager(s) and member(s) can do this. The manager can edit/delete any of these list/items. However, members can only operate on their own lists/items.
- **Freeze the list/items**: After a list or a root item is finalized, the topic manager needs to "freeze" it to prevent it from any further changes. If later on, changes need to be made on a frozen list/item, the topic manager needs to "Open" it.
- **Grant vote on a list**: Topic managers/members/voters can only vote on a list after it has been granted for voting. If a list is finalized and ready for a vote, the topic manager needs to "Freeze" it first. After a topic is "Frozen", the topic manager can then "Grant a Vote" for it.
- **Stop vote on a list**: Whenever the group wants to stop the vote on a list, the topic manager needs to "Stop Vote" on it. He/She can grant a new vote session on this list later if needed.
- **Vote on a list**: During the voting period, by clicking "Vote" button in the top frame, all the lists available for voting will be displayed in the right frame. Voters can select the one they want to vote. Or they can just display the list and click the "Vote" button above the list to vote. A voting window will appear. By default, a voter's last voting result will be displayed. Voters must vote on all the list items according to corresponding rules, otherwise an error message will be displayed.
- **Display voting result**: After the vote is submitted, the voting result will be displayed immediately. Voters can check the voting result by many different ways, such as data table, or graphically (bar/pie/line, etc.).

- **Check voting result**: To check the voting result, click the "Result" button in the top frame, pick the list to check, and the result will be displayed in the right frame window. Alternatively, a user can just display the list in the right frame window, and click the "Result" button above the list to view the voting result.

5.5 User Feedback

So far about 300 users at NJIT have used the SDSS system (the List Gathering Tool only, the Dynamic Voting Tool only, or the combined SDSS Toolkit). Meanwhile, all the users have also been trained and used WebBoard – a Web-based conferencing system used for course learning at NJIT. A System Survey (see Appendix E) has been conducted to track user feedback towards the SDSS system. Below is some of the significant feedback gathered from this System Survey.

The Dynamic Voting Tool stand-alone version has a very simple and easy-to-use user interface as compared to the List Gathering Tool or the combined SDSS Toolkit. On the other hand, it is certainly less powerful in terms of functionality because the List Gathering procedure is to some extent simplified. Yet, users seem to like the style a lot as is reflected in the results of the first part (Question 1 to Question 28) of the System Survey. The second part of the System Survey (Question Q2.1 through Question Q2.6) is six open-ended questions as listed below.

- Q2.1 Which features do you think are the most useful?
- Q2.2 Which feature do you think is the least useful?
- Q2.3 What features should be added to this system?
- Q2.4 What features should be removed from this system?
- Q2.5 What changes would you recommend to make the system easier to use?

- Q2.6 What changes would you recommend to make the system more effective for the task you were given?

Some significant user comments concerning the above questions are discussed separately in the following sections. Generally speaking, these comments provide an evaluation of the system and are quite positive towards the system. Meanwhile, they also lead to the direction of future improvements.

5.5.1 Most Useful Features

The most typical and encouraging comments are "All of the features", "The Voting Tool is very useful", "The voting tool itself is quite useful" etc. Table 5.2 below lists some typical comments and sorts these comments into categories.

Table 5.2 Most Useful Features

User Comments		Analysis by Category
Voting Tool Only	• "The various statistical results that came with the voting tool was very helpful. This allowed myself to interpret the results in various ways." • "voting tool- result analysis system" • "The automatic voting distribution calculations" • "the display of the charts and raw data of the votes and the calculation of the votes was most useful." • "The voting setup, with revotes, instant feedback, ability to be anonymous"	Voting result presentation
	• "The Voting system was key in taking the "majority rules" approach to formulating a group answer." • "The voting sessions are very helpful in decision making."	Facilitate decision-making
	• "Reliability and speed"	System reliability and speed
	• "The training material was really helpful" • "The help option and training." • "help options description of system"	System help file and training materials
	• "Giving Ideas and then voting on the same" • "Ability to post and exchange ideas using WebBoard. Explicit importance of criteria to members of the group was clearly known by using Voting Tool."	Be able to first collect ideas then vote on them.
SDSS Toolkit	• "Voting is useful to come up with a consensus of the group" • "Voting feature: you can ask members to vote on the elements of an *unambiguous list*." • "Vote, so you can see other guys' opinion." • "I really enjoyed the voting aspect, I think this was an effective way to develop a group consensus/decision. The analytic voting breakdown was also interesting."	Enhance group consensus
	• "The voting features" • "Voting system was very useful." • "Voting sessions are most useful."	The voting feature
	• "The immediate analysis of the voting, particularly the rank ordering." • "Voting is a good feature and proving results via various reports is very good." • "The Yes/No voting and the rank order voting in the SDSS Toolkit. I also feel that the result table and alternative display ways are helpful." • "The voting functions and the result displays are excellent!"	Voting and Voting result presentation
	• "Ability to change votes if more information became available"	Dynamic voting feature

5.5.2 Least Useful Features

The most typical and encouraging comments are "It appears that all implemented features are useful", "Nothing was un-useful. Everything was useful. Except information overload." Table 5.3 below lists some typical comments and sorts these comments into categories.

Table 5.3 Least Useful Features

User Comments		Analysis by Category
Voting Tool Only Or SDSS Toolkit (the voting part)	• "Every thing was useful to make the system work correctly." • "Personally, I like all feature of system, so I cant say anything about least useful feature." • "None. All the info was important and useful" • "It is pretty well thought out, nothing frivolous or extraneous." • "There were no features that were the least useful."	Totally positive
	• "Unless you are a statistics buff, there were too many statistical distributions." • "All features were useful in different ways, however in Voting tools without knowing the meaning of different methods of measuring results, those methods were of little help."	Understanding of the voting calculation methods
	• "Opening of frames in Different Windows"	Too many pop-up windows
	• "The links, there where too many links"	Too many links

It is quite clear that a group has to learn such a system over a period of time in order to begin to appreciate a number of the statistical approaches used. An analysis such as the Thurstone's Law analysis is far more useful for understanding the group rating of a large list of items than is a rank order summary, but it is more complex.

The resulting interval scale provides a very natural way of determining how the individual items actually cluster in to unique items or groups of similar items by the actual distance on the scale between items.

Also associated with this need to learn a new way of viewing the results of a voting process is the assumption that a significant number of students expressed that they had, up to now, considered a voting process as a process to make a final decision as opposed to focusing further exploration of the discussion.

5.5.3 Features That Should Be Added to The System

A lot of good comments were collected besides comments such as "There is nothing that needs to be added." Or "I think the system is fine the way it is." Or "With current features the system is effective enough to carry out the experimental task properly." Most suggestions concentrated on the user awareness and better group coordination that is the core of such an asynchronous collaborative system. Table 5.4 below lists some typical comments and sorts these comments into categories.

Table 5.4 Features That Should Be Added to The System

User Comments		Analysis by Category
Voting Tool Only Or SDSS Toolkit (the voting part)	• "Better Icons and Graphics" • "The voting tool must be improved, the layout has to be changed and more functions can be added." • "A discussion section. It should also be a little easier (less screens) to see voting results, especially raw data (ie. to be able to tell who voted on what)." • "Features such as vote of root items, contact information of the group members." • "More visually appealing, such as graphics." • "E-mail Feature, so that group members can just write E-mail to each other if they want to write privately to some member" • "Where an item got voted by all members (and accepted) should not be included in second voting round to avoid confusion and decision abnormality. Another minor change, that is the column of 'votes needed' in left side screen should be separated a little bit"	Improve user interface & functionality
	• "It may be helpful if the group coordinator could set up the voting sessions. This would allow the sessions to be set up and customized specifically for the group needs." • "I would like to give control of freezing and starting the voting rounds in the control of the group coordinator"	Voting sessions controlled by the group manager
	• "It may be overkill, but to be a true collaborative tool this system should be integrated with a document management system. A case in point is that my assignments were bulleted as specified in the sample document. Posting it on the board, I lost that. "	Add document management
	• "Instant Alert that another user has logon to the system" • "I would add a clock counting back to the deadline." • "Tracking group member's participation, we always had to wait for someone's vote, that delays our overall decision. We can give everyone credits if he/she provides more information."	Provide user awareness
	• "Chat feature, instant messaging" • "Voice so that the team can talk to one another" • "Easier chat capability with online users." • "Would it be possible to schedule a real time chat conference into the system?" • "Better interaction, more live, maybe like a class chat room. So that we can have meeting and interact better." • "pager: so you could send message to someone who is also logged in."	Add online chatting support (synchronous features)

Table 5.4 Features That Should Be Added to The System (Continued)

User Comments		Analysis by Category
Voting Tool Only Or SDSS Toolkit (the voting part)	• "Integrate it w/ webboard. It was cumbersome to go back and forth between two systems to discuss and vote. These should be inter-related." • "Email to grp participants so we don't have to switch between webboards."	Be able to integrate to other Web-based conferencing systems
	• "Feature that allows you to export results using excel"	Export voting results to local
	• "Additional "time" to analyze and select the options. (i.e. Two (2) weeks versus one (1) week."	Give more time on voting
	• "A simple text search that can search through the entire board, or user specified threads."	Add search function
	• "There should have been a more organized general discussion are for each group"	Provide structured list-gathering feature
	• "More step by step instructions"	Have better instruction

The ability to communicate effectively both synchronously (better help with instant messenger, chat, or email notification) and asynchronously (provides the status of the member participation) is really important in all collaborative systems. User feedback strongly reflects such demands. This is definitely something that needs to be integrated into the system in the near future.

Most users were not knowledgeable on decision support voting methods and therefore the author did not get feedback on the types of improvements needed to expand the scope of the types of applications this system can be applied to. It is clear, however, that this is an important next step in the evolution of this system.

5.5.4 Features That Should Be Removed From The System

Most users didn't provide much opinion on this question. The most typical comments are: "No comments." Or "I didn't see anything that should be removed." Below are some similar comments:

"Everything seems to be just right".

"As far as I am concerned all the features if properly used and understood by everyone are useful in different ways, therefore I would not remove any."

"Though there are some extra things, but the system is so versatile that I don't think what needs to be removed."

However, there is some confusion about the concepts "Freeze" vs. "Close". The Following comments reflect this:

"Vote Frozen status and vote closed status."

"Freeze and close seem to be similar functions."

"Freeze."

In the SDSS Toolkit, the concepts "Freeze" and "Close" have clearly defined different functions; therefore, they shouldn't be mixed or removed. Better training and explanation are needed to clarify these concepts to the users in the future.

5.5.5 Changes Recommended to Make The System Easier to Use

Most users gave very positive comments on the system, and the most encouraging comments are statements like the following: "I think it is very easy to use, once the training tasks are completed." "None. At first the system seemed a little confusing but after using it two or more times everything began making sense." "I think that the system is easy to use, actually I like it more than WebBoard." Table 5.5 below lists and categorizes some typical comments concerning the improvements of the system in terms of making the system easier to use.

Table 5.5 Changes Recommended to Make the System Easier to Use

User Comments		Analysis by Category
Voting Tool Only Or SDSS Toolkit (the voting tool part)	• "The information overload should be taken care of."	Still need to find a better way to organize the lists
	• "More user-friendly interface, while the system was very easy and straightforward to use, it was plain; I think it could have been a little more vibrant to spark creative discussion." • "Make voting session URL and information more visible." • "Nicer GUI, easy to use navigation." • "Make it more user friendly" • "Buttons and Icons. Most were just text links." • "Less hyperlinks on the main page." • "Better web technology and interface" • "Log in page may be easier" • "Make it easier to refresh changes." • "Larger Font" • "Have vote button in the folder so don't have to go to the main button."	Improving user interface
	• "When voting for relative orders, the rating that you select should not be available on a subsequent questions. You may have left this like that on purpose, a suppose you have good reasons."	Change the way of displaying voting items
	• "It should be a little quicker" • "It needs to be a little quicker."	Enhance the speed especially when # of items are larger
	• "Add a chat room setting."	Provide chatting
	• "Each new system has it's own learning curve and if the audience/participants will be coming from any particular group (say students), if the look and feel of system they are familiar with is copied, it will be much easier to adapt." • "Make it more like WebCT"	Adopt the popular look and feel of conferencing system
	• "Combine both websites (*the WebBoard and the Voting Tool*) into one. Have only one login."	The stand-alone version should be able to seamlessly integrated into other existing systems.
	• "The system is well organized. I wouldn't request any changes. I would like to add a option that would show if other members of the group are logging on to the system while you are logged on."	Provide user awareness mechanism
	• "Add feature that allows you to export results using excel"	Allow user to manipulate the result locally

Table 5.5 Changes Recommended to Make the System Easier to Use (Continued)

User Comments		Analysis by Category
Voting Tool Only Or SDSS Toolkit (the voting tool part)	• "System is quite easy to use. Tutorials are also helpful in understanding the system objectives. Following the directions in tutorials and doing pre-task exercise is in my opinion enough to be able to use the system." • "The voting tool training can be improved. More detailed training can be given." • "There should be sample movies to show how to use the system, because aged people don't understand the system really fast."	Improve training, giving more detail
	• "I feel one of the problems when using the system is in voting. I realized that this problem causes confused for users in doing the task. Although "help" shows the way to vote, when going to the voting session, there are some difficulties in implementing."	Need to improve the training session to deal with such confusions on the voting routine.
	• "No changes required. Once the instructions are well understood it is not hard to use. But MACINTOSH users should be warned that it's not going to work at its best on that operating system. I had that problem when I was looking at the results from the Votes"	Be aware of different system (and browser) compatibility

5.5.6 Changes Recommended to Make The System More Effective

Of the various user feedbacks on this question, most comments are also quite positive. The most encouraging comments are: "I recommend no changes. It is great, understandable, and user-friendly in my opinion. I had no problems using it." "The current system is fine for the given task." "The way the system is it was effective for me." And so on. Table 5.6 below lists some valuable comments concerning the system improvements in terms of effectively carrying out the tasks, and briefly analyzes these comments into categories.

Table 5.6 Changes Recommended to Make The System More Effective

User Comments		Analysis by Category
Voting Tool Only Or SDSS Toolkit (the voting part)	• "It should be quicker" • "Only to speed up the system, the mechanics are already set up very well, but sometimes when posting a new thread or reply, there were long pauses."	Improving the speed
	• "There is an unfortunate rigidity when the subject was forced to rank items even if he felt that many were irrelevant to the absolute criteria category. A separate function should be created to address such issues: "Is this item relevant?" (Y/N)."	Add relevance-check on voting items
	• "Combine both tools (Webboard Discussion and Voting Tool) into one interface"	Integrate voting tool seamlessly into other systems
	• "The screen should be refreshed automatically." • "Clear definition of open and closed forums, clear definition of deadlines for voting." • "The Add Item feature was confusing. I was never sure whether I was adding an item to an existing vote or adding a new vote all together. This menus need to be labeled better." • "Automated deadlines for different tasks can be put into the system. System should check for postings by a particular member and warn him if he is not participating properly in the discussions. The voting tool can be made more user friendly." • "Frames should all load into one screen." • "Less links" • "Make it like WebCT so its easier to post and reply"	Improving user interface
	• "Instant messaging to let users know that there will be a meeting so everyone will likely participate" • "A synchronous chat option." • "It would be helpful if we could chat online. It was increasingly frustrating to wait for a feedback." • "I would like to have the members notified when new messages are posted on the webboard. This would give them a reminder that they should participate and also prompt feedback. I feel that I would have gotten more discussion out of my group if this happened" • "May be to add chatting tool, so that group member can communicate better" • "Better methods of communication." • "Search options and live chat with members." • "The system should have shown if other members of the group are logged on at the same time when you log on and allow direct communication with the other members of the groups. That would save time."	Provide better user awareness and communication with synchronous tools (like chatting) and user status report

5.6 Future Improvements

Based on the user feedback gathered mainly from the System Survey, and the observations and reflections of the author during designing and implementing of the Dynamic Voting Tool, the following issues need to be taken further care of in the future.

5.6.1 General System Design

In terms of the functionality, as mentioned in sections 5.5.3, 5.5.5 and 5.5.6, the ability to be able to communicate effectively both synchronously (better assisted with instant messenger, online chat, or email notification) and asynchronously (provides the status of the member participation) is really important in all collaborative systems. User feedback strongly reflects such demands. This is definitely something that needs to be integrated into the system in the near future. Some other features would also be helpful if added into the system, such as,

- Allow users to export the voting result locally and be able to manipulate it by using system analysis tools.
- Add relevance-check on voting items during voting.
- Be able to seamlessly integrate the voting tool into other Web-based conferencing systems
- Add search function

In terms of usability, refer to the comments in sections 5.5.3, 5.5.5 and 5.5.6. Although most users are quite satisfied with the GUI of the current system, there are still rooms to improve it. All the suggestions from the users listed in Tables 5.4, 5.5 and 5.6 can be good guidelines. Of those ideas, the points that need more concern is to be aware of system compatibility with different platforms, and adopt the popular look and feel of existing Web conferencing systems.

System speed is another key issue. When the number of users and the number of items are small, the speed is not a problem, but when the numbers get larger, the system could be noticeably slower. The limitation of the ColdFusion5 language is one reason for this problem. Further research is also needed to improve the voting result calculation algorithm and the code efficiency to deal with this problem.

Good system tutorials and training is another key for the successful use of the system. In the future, the training materials should not only include how to use the system, but how to understand the different voting and statistical methods that have been applied to the system, so that users can have a better understanding of the results.

5.6.2 Control of Voting Process

In the whole process of voting, there are many places needing appropriate voting control. Future work should include the following considerations:

- The voting initiator can prohibit any changes except the one of voting and he or she can choose from a list of voting options.
- When starting the voting there is a condition that no one can view the results until a certain number or certain percentage of the votes are in. If it is a non-public fixed list they could specify it either way, if it is public they will express a number.
- When there is a list of members with their email in the group, when the votes become viewable each member is sent a message informing them of it and containing a direct link to view the votes. View votes would also be in the

standard interface which when you come in would show how many have voted and how many are needed to make the vote viewable.

- If the owner decides to make a change in one of the items during the voting then he or she has the option of zeroing out the vote for that term. If this is done when a person signs in who has already voted they need to be told they need to revote only on that item. The votes on that item are not viewable until there are enough votes on it (preset the criteria).
- A proper approach is needed to make the list process more dynamic by allowing certain types of voting to occur while the list is undergoing change by new additions and deletions in order to cut down information overload by pruning the list dynamically over time.
- The system should provide priority setting with rank order voting with multiple ties to allow such applications as task generation and assignment in maintenance operations. Such a voting process would have to be truly dynamic in that the list would be changing while the voting is going on.
- Improving the ability of a group member to learn and assume a manager role, or to try and allow the group to manage the process by such things as having an on going vote in the list generation process as to when the group wants to start a voting process. Letting the group use a group process to control the meta-process decisions is a whole open-ended research area.
- The system should allow users to download current voting status to the local machine, and run analysis of the voting strategy stand-alone without affecting

the voting system. This operation may help individuals understand the situation, and may speed decision-making.

- Ideally, voting items should be able to appear on the screen randomly, or in reverse order, so as to counter-balance the order bias.

CHAPTER 6

EXPERIMENTAL DESIGN AND PROCEDURES

In this research, the main concern is using appropriate decision tools and procedures to facilitate small group decision-making, especially a full understanding by the group of individual preferences among its members. Moreover, it is hoped that these tools can aid in determining the degree of understanding and consensus at any time in the group process. The design and implementation of the Social Decision Support System (SDSS) Toolkit is the first step to build such a group decision support tool. And as a result of being able to accomplish this, it is hypothesized that one will obtain more accurate group judgment than without the support of the tools; that is, the group will be more likely to develop a group view of complex problems that is more consistent with the views of the members at the end of the process. Furthermore, consensus of the group will be either enhanced, or the lack of consensus will be better understood by the individual members in the group, so that the overall accuracy of the group judgment, and the perceived satisfaction of the group will be improved. Finally, the improved group process will lead to a better quality of the decision-making both as perceived by the group members and objectively measured by external judgment. And meanwhile, the overall perceived satisfaction level would be improved.

As an effort to reach these goals, two PhD students at NJIT – Zheng Li and Yuanqiong Wang – have designed and developed a new Web-based collaborative Social Decision Support System (SDSS) Toolkit that is composed of two main parts: a List Gathering Tool and a Dynamic Voting Tool. The rich features in the List Gathering Tool and the Dynamic Voting Tool were designed to allow group members to contribute their individual ideas in a very well structured way, and be able to catch the group view instantly in different ways by using the Dynamic Voting Tool. As briefly discussed in the previous chapter, the List Gathering Tool is to provide fundamental structures under other components in the toolkit to help groups organize their ideas into different lists, such as lists of criteria or alternatives. It was designed and implemented by Yuanqiong Wang. The Dynamic Voting Tool is used to help groups obtain individual preferences on the formed lists, and help form group preferences. It is designed and implemented by the author (i.e., Zheng Li). For example, when users carry out a decision-making task using the Dynamic Voting Tool, the List Gathering Tool may help one to effectively identify all the criteria in a structured way, and then each member in the group may choose to vote on the alternatives using appropriate voting methods. Based on the individual voting result, the group can form a single group opinion on what are the final criteria the group chooses.

A controlled laboratory experiment was conducted to test the effects of the new SDSS Toolkit, including the effect of Human Dynamic Voting (HDV) Tool, the effects of the List Gathering Tool, and the combination of the two toolkits interacting with group processes. Li and Wang have jointly conducted the experiment using the same task, procedures and experimental instrument. In this research, the author will report the effects of the Dynamic Voting Tool with and without the interaction of the List Gathering Tool. And Yuanqiong Wang will report the effects of the List Gathering Tool with and without the Dynamic Voting Tool in her research.

In addition, as will be reported in Chapter 8, the SDSS Toolkit (List Gathering Tool + Dynamic Voting Tool) was utilized and separately evaluated in field trials in several courses at NJIT. Li and Wang conducted the field studies together and will jointly report the results in their dissertations.

6.1 The Experimental Design

6.1.1 Independent Variables

This experiment has two factors: the effects of the List Gathering Process (with tool support/manual process) and the effects of the Human Dynamic Voting Process (with tool support/manual process). Taken together, the combinations of the independent variables yields four experimental conditions as shown in Table 6.1 below:

Table 6.1 Independent Variables

Conditions		List Gathering Process	
		List Gathering Tool	**Manual**
Human Dynamic Voting (HDV) Process	**Dynamic Voting Tool**	**Condition 1: LV** List Gathering Tool + Dynamic Voting Tool	**Condition 2: NV** No List Gathering Tool + Dynamic Voting Tool
	Manual	**Condition 3: LN** List Gathering Tool + No Dynamic Voting Tool	**Condition 4: NN** No List Gathering Tool + No Dynamic Voting Tool (WebBoard only)

The SDSS toolkit (i.e., List Gathering Tool + Dynamic Voting Tool) was a Web-based toolkit. Users could access it at any time anywhere via the Internet. Therefore, in the experimental design, the communication mode was asynchronous only. There was no face-to-face meeting in the whole experimental process. Condition 4 (manual List Gathering Process + manual Dynamic Voting Process) was the baseline condition. It used an asynchronous conferencing system (i.e., WebBoard) to carry out the experimental task, without any other structured toolkit support. Conditions 1, 2, and 3 used WebBoard plus one of the tool conditions (List Gathering Tool, Dynamic Voting Tool, or SDSS Toolkit) to carry out the task.

6.1.2 Dependent Variables

A Post-Questionnaire (see Appendix F) was used to measure the following major variables (in Part I):

- Perceived quality of decision-making
- Perceived satisfaction (solution satisfaction, process satisfaction)
- Process gains and losses
- Conflicts and consensus

The quality of decision-making was also subjectively measured by expert judgment. It was judged by two separate teams of selected experts based on groups' final reports. The detail process is described in Section 6.4.2.

Besides measurement by the Post-Questionnaire, the conflicts and consensus levels were also intended to be measured by the Task Survey (see Appendix D) and experimental transcripts. That is, pre-task initial ideas used to measure initial consensus, group final reports used to measure group consensus, and ideas after group discussion (from Task Survey) used to measure post-task consensus. Comparing these data would provide an insight into the consensus change in a group process.

Some other effects were also measured by the Post-Questionnaire (in Part II), such as group behavior, cohesion, participation, and leadership, etc.

However, in this dissertation, only the results of the quality of decision-making (measured by Post-Questionnaire and expert judgments), and perceived satisfaction (solution satisfaction and process satisfaction) were analyzed and reported. The researchers also conducted transcript analysis on some behavioral measurement, i.e., counted the length of comments and the average number of words of comments that (1) in each condition; (2) belong to coordinators/members. The data were analyzed using ANOVA to find the patterns of participation.

Due to limited time, data analysis results on all other variables, such as process gains and losses, conflicts and consensus, participation, etc., will be further analyzed and reported later.

6.1.3 Task

A Computer Purchasing Task was used in this experiment (See Appendix A). This was a decision-making task (type 4) (McGrath, J. E., 1984), which is to develop group consensus on issues that do not have correct answers. The answers are open-ended and the quality of the decision-making has to be judged by experts in this field. Such a task may well involve groups to solve the problem rather than individuals. As McGrath (1984) pointed out:

> Groups may have some natural disadvantages, ... They may not utilize fully or efficiently the range of knowledge they contain. Some members may have more influence than others, and more than their knowledge or task competence would warrant. There may be pressure to agree, tending toward quick rather than good decisions. And the very diversity of knowledge among

members may carry with it a diversity of views and values, some of which may be hard to reconcile into a single group decision.

The author believes that using such a decision-making task to test the effects of the SDSS Toolkit may well establish the diversity of group views among group members, and it may overcome some of the disadvantages of small group decision-making and to some extent facilitate group process, which is the goal of this research.

In addition, the task is a real life scenario at NJIT. Each year, NJIT provides free PCs to freshmen, and a task force has been used for the similar task as described in the experimental task. The experimental results will be useful to the school and it will be convenient to have members from the task force to act as the expert judges to evaluate the quality of group decision-making.

Besides, the task was carefully designed to fit the SDSS Toolkit in two ways. First, it explicitly required group members to create at least two sets of criteria, and gave reasons, which is a good task for the List Gathering Tool. Second, it explicitly asked group members to use the "Yes/No" vote and the "Rank Order" vote to the created list items, which fitted well to the Dynamic Voting Tool.

To make sure the subjects concentrated on the major goals, a "Final Report Template" had also been provided to groups, with clear guidance on the format and the contents of the report. Therefore, the groups would not need to put extra effort on the producing of a real RFP, and their final reports would have consistent format and would be easier to extract relative information from corresponding sections.

6.2 Hypotheses

In this dissertation, data collected about the dependent and independent variables were used to test the following hypotheses. These hypotheses were formed based on the hypotheses drawn in Chapter 4 (Section 4.3).

1. Perceived Quality of Decision-making

H1. (*Perceived quality of decision-making*) Groups with SDSS Toolkit support will have higher perceived quality of decision-making than groups without SDSS Toolkit support.

H1a. Groups with Dynamic Voting Tool support will have higher perceived quality of decision-making than groups without Dynamic Voting Tool support.

H1b. Interaction (Synergistic Positive): Groups with both List Gathering Tool and Dynamic Voting Tool (i.e., SDSS Toolkit) support will have disproportionately high perceived quality of decision-making.

2. Quality of Decision-making (Expert Judgment)

H2. (*Quality of decision-making*) Groups with SDSS Toolkit support will have higher quality of decision-making than groups without SDSS Toolkit support.

H2a. Groups with Dynamic Voting Tool support will have higher quality of decision-making than groups without Dynamic Voting Tool support.

H2b. Interaction (Synergistic Positive): Groups with both List Gathering Tool and Dynamic Voting Tool (i.e., SDSS Toolkit) support will have disproportionately high quality of decision-making.

3. Perceived Satisfaction (Solution Satisfaction, Process Satisfaction)

H3. (*Perceived solution satisfaction*) Groups with SDSS Toolkit support will be more satisfied with their solutions than groups without SDSS Toolkit support.

H3a. Groups with Dynamic Voting Tool support will be more satisfied with their solutions than groups without Dynamic Voting Tool support.

H3b. Interaction (Synergistic Positive): Groups with both List Gathering Tool and Dynamic Voting Tool (i.e., SDSS Toolkit) support will be disproportionately more satisfied with their solutions.

H4. (*Perceived process satisfaction*) Groups with SDSS Toolkit support will be more satisfied with their group process than groups without SDSS Toolkit support.

H4a. Groups with Dynamic Voting Tool support will be more satisfied with their group process than groups without Dynamic Voting Tool support.

H4b. Interaction (Synergistic Positive): Groups with both List Gathering Tool and Dynamic Voting Tool (i.e., SDSS Toolkit) support will be disproportionately more satisfied with their group process.

4.Group Behavior (Comment Length, Degree of Participation, Leadership)

In terms of the group behavior, since the SDSS Toolkit provided a structured way for contributing ideas and exchange messages, and with instant feedback of voting results to enhance understanding and expose inconsistencies, it is supposed to be more efficient then without it, and would produce equal or more amount of information to carry out the task with less exchange of messages/comments among group members which was measured by the comment length, and less degree of participation which was measured by the average number of words. (Note that perceived participation was also measured by the Post-Questionnaire, but was not analyzed and reported in this dissertation.)

In addition, as group coordinators were required to monitor the whole group process during group discussion, and needed to determine when to initiate and terminate a voting session, it is supposed that the heavier responsibility would yield greater amount of messages/comments than ordinary group members in general. On the hand, with the support of the Dynamic Voting Tool, conducting a voting session would be much more easier than without it. Therefore, the comment length of the coordinator is supposed to be considerably shorter with the support of the Dynamic Voting Tool than without it.

Overall, the following additional hypotheses were proposed:

H5. (*Comment length*) Groups with SDSS Toolkit support will have shorter comments than groups without SDSS Toolkit support.

H5a. Groups with Dynamic Voting Tool support will have shorter comments than groups without Dynamic Voting Tool support.

H5b. Interaction (Synergistic Positive): Groups with both List Gathering Tool and Dynamic Voting Tool (i.e., SDSS Toolkit) support will have disproportionately short comments.

H6. (*Degree of participation*) Groups with SDSS Toolkit support will have less degree of participation than groups without SDSS Toolkit support.

H6a. Groups with Dynamic Voting Tool support will have less degree of participation than groups without Dynamic Voting Tool support.

H6b. Interaction (Synergistic Positive): Groups with both List Gathering Tool and Dynamic Voting Tool (i.e., SDSS Toolkit) support will have disproportionately less degree of participation.

And for the role of group coordinator,

H7. Coordinators in groups with Dynamic Voting Tool support will have shorter comments than coordinators in groups without Dynamic Voting Tool support.

H8. Group coordinators will have longer comments than other group members.

Note that in all the above hypotheses, "without Dynamic Voting Tool support" refers to the baseline condition (i.e., WebBoard only condition).

6.3 Experimental Procedures

During Summer 2001 to Fall 2002 semesters, the experiment was conducted in two stages: pilot study, followed by the formal experiment.

6.3.1 Pilot Studies

The first pilot study was conducted during Summer 2001 to test the experimental task, instruments and procedures. 11 subjects from the CIS677-850 course (a DL section) participated in this study. The subjects were randomly assigned into two groups (5 and 6 persons per group). The experiment condition was the baseline condition (condition 4) – WebBoard only asynchronous group discussion. The main purpose of this pilot study was to test the task (whether it is fit for group discussion, whether the description is clear, etc.), the experimental procedures (whether all the questionnaires were correct and good to use, etc.), and the procedures (whether the procedures were feasible and easy to follow, etc.). This pilot study was successful and satisfying results were obtained. Based on the pilot study, slight modifications were made to the task description, the experiment procedures, and the questionnaires.

After the pilot study, the experimental design and instruments were submitted to the NJIT IRB for Human Subjects Research, and the research plan that involved using NJIT undergraduate and graduate students for the controlled experiment was approved. (See Appendix G for the Review Form.)

The SDSS Toolkit was developed during Fall 2001 and Spring 2002. Upon the completion of the SDSS Toolkit, another pilot study was conducted to test the effects of the toolkit before the formal experiments started. This second pilot study was conducted during Summer 2002. In total 37 graduate students from CIS 675-850 and CIS 677-850 (both DL sections) participated and 33 subjects completed the task. These subjects were randomly assigned into six groups. Experimental conditions 1, 2, and 3 each had two groups which consisted of 6-7 subjects.

Overall, the study was quite successful in terms of the whole process and participation, although the results were not very good. The subjects didn't use the SDSS Toolkit, especially the Dynamic Voting Tool, for their experimental task as much as expected. Based on this study, the instructions and procedures were slightly modified to make the instructions and the descriptions of the procedures for each condition more accurate and specific. There were groups that spent lots of times learning how to create a nice RFP for the final report, instead of working on the creating of criteria lists. This motivated the researchers to modify the experimental task and provide an additional "Final Report Template" for all groups in the following experiment. Furthermore, the

SDSS Toolkit was improved substantially in terms of interface and functionality, based on user feedback from this pilot study.

6.3.2 Formal Controlled Experiment

The pilot studies consistently indicated that the experiment was viable. Therefore, two formal experiment sessions had been conducted during Spring 2002 and Fall 2002 semesters, following the pilot studies.

In Spring 2002, since the SDSS Toolkit was still under development, a formal experiment was conducted on the baseline condition only (i.e., WebBoard only). In total 44 graduate students from CIS 675-852, CIS 675-854 (both DL sections) and CIS 675-102 (a Face-to-Face section) participated and 42 subjects successfully completed the task. The subjects were randomly divided into seven groups and each group had six subjects.

In Fall 2002, the experiment was continuously conducted on all four experimental conditions. In total 208 student subjects from both graduate and undergraduate levels participated in the study and 178 subjects successfully carried out the whole task. Undergraduate students were introduced into the experiment without any pilot study tests due to the dramatic shrink of the student body at the graduate level at NJIT during the period this study was conducted. For the same reason, the student subjects were subscribed from a wider scope of the courses compared to the pilot studies. The courses that were involved in this study are listed in Table 6.2 below.

Table 6.2 Courses Used For the Experiment

Time	Course	Section	Type	Course Title
Summer 2001*	CIS 677	850	DL	Information System Principles
Summer 2002*	CIS 675	850	DL	Evaluation of Information Systems
	CIS 677	850	DL	Information System Principles
Spring 2002	CIS 675	102	Face-to-Face	Evaluation of Information Systems
		852	DL	
		854	DL	
Fall 2002	CIS 350**	101	Face-to-Face	Computers and Society
		103	Face-to-Face	
		451	DL	
	CIS 465**	101	Face-to-Face	Advanced Information Systems
	CIS 602	101	Face-to-Face	JAVA programming
	CIS 675	101	Face-to-Face	Evaluation of Information Systems
		851	DL	
	CIS677	101	Face-to-Face	Information System Principles
		851	DL	
	CIS 635	101	Face-to-Face	Management of Telecommunication
	MIS 645	101	Face-to-Face	Managing IT for Competitive Advantages
		851	DL	

* Means it was a pilot study
** Means it was an undergraduate course

6.3.3 Subjects

NJIT undergraduate students and graduate students were used for the experiment. The students were picked from the courses related to decision-making and requirement analysis. Student subjects could choose to participate in the experiment voluntarily, and earned course credit (about 15%) by participating the experiment. Meanwhile, other alternative tasks were also available to the students if they chose not to participate in the experiment, or quit during participation. There was no penalty there.

Subjects were randomly assigned to conditions/groups where possible. The group size was five to seven persons per group. Each group performed exactly the same training and experimental task, and completed the same set of questionnaires. Table 6.3 shows the number of subjects participated in this experiment.

Table 6.3 Subjects Summary

Time	Undergraduate		Graduate		Total	
	Total	Valid**	Total	Valid**	Total	Valid**
Summer 2001*	-	-	11	11	11	11
Summer 2002*	-	-	37	33	37	33
Spring 2002	-	-	44	42	44	42
Fall 2002	85	80	123	98	208	178

* Means it is a pilot study.
** Valid means the subject has gone through the whole process successfully.

During the experiment, after submitting the Consent Form (see Appendix B) and Background Questionnaire (see Appendix C), some subjects never showed up again after they were assigned into groups, and some subjects dropped out of the experiment in the middle. Due to the loss of subjects in the end, those groups with a number of subjects below five had to be discarded. There are two other groups that had serious problems (very little participation and group discussion) during the experiment. Although they finished the process, their data also had to be discarded. Table 6.4 below shows the distribution of the groups and the valid number of subjects for the formal experiment (including Spring 2002 and Fall 2002).

Table 6.4 Summaries of Subject Groups (by Condition)

	Condition 1: LV		**Condition 2: NV**		**Condition 3: LN**		**Condition 4: NN**	
	Group ID	Size	Group ID	Size	Group ID	Size	Group ID	Size
Graduate	GLV01	6	-	-	GLN01	6	GNN01	6
	GLV02	6	GNV02	5	GLN02	6	GNN02	6
	GLV03*	5*	GNV03*	4*	GLN03	6	GNN03	6
	GLV04*	4*	GNV04	6	GLN04	6	GNN04	6
	GLV05	6	GNV05*	4*	GLN05	6	GNN05	6
	GLV06	6	GNV06	6	GLN06*	5*	GNN06	6
	-	-	GNV07	5	-	-	GNN07	6
Subtotal:	6	33	6	30	6	35	7	42
Under Graduate	GLV10	5	GNV10	5	GLN10	6	GNN10	6
	GLV11	6	GNV11	7	GLN11	7	GNN11	6
	GLV12	5	GNV12	7	GLN12	5	-	-
	GLV13	6	GNV13	5	GLN13*	4*	-	-
Subtotal:	4	22	4	24	4	22	2	12
Total:	**10**	**55**	**10**	**54**	**10**	**57**	**9**	**12**
Valid:	**8**	**46**	**8**	**46**	**8**	**48**	**9**	**54**

* Means the group has been discarded in the final data analysis.

Table 6.4 clearly displays the total number of groups and the total number of subjects within each experimental condition. Added together, the total number of valid groups is 33, and the total number of valid subjects is 194. However, of the valid subjects, 6 of them failed to complete the Post-Questionnaire, the Task Survey and the System Survey; and one subject gave invalid answers to the questionnaires and had to be removed from the final data. So the total number of subjects with valid data is 187.

6.3.4 Experimental Procedures

During the experiment, the researchers (i.e., Zheng Li and Yuanqiong Wang) strictly followed the following experimental procedures (see Table 6.5 below) for experimental conditions 1, 2 and 3 (i.e., LV, NV, and LN):

The procedures for the baseline condition (i.e., WebBoard only) were exactly the same as above except that subjects didn't have the two-day tool (List Gathering Tool, Dynamic Voting Tool, or SDSS toolkit) training. Besides, the System Survey was not required for the baseline condition.

Table 6.5 Experimental Procedures (for Conditions LV, NV & LN)

No.	Task	Time Period
1	Distribute and Collect Background Questionnaire and Consent Form.	One month before the experiment starts
2	Analyze Background Questionnaire and assign subjects into different groups.	One week before the experiment starts
3	Create a board for each group. Create conferences (Instructions, Self-introduction, Practice, Rules, Task and Procedures, Initial Ideas, Discussion Area, Final Report) in each board.	Three days before the experiment begins
4	Send welcome E-mails to subjects with experimental overview, and the URL for the groups in the first day of the experiment. Give subjects two days to finish the WebBoard training tasks. Give another two days for Tool (list gathering tool, voting tool or SDSS toolkit) training.	WebBoard Training (two days) Tool Training (two days)
5	Check whether or not subjects have finished all the training tasks by the training ending date. If the subjects have not finished all the training tasks, send email to remind them.	Before the end of training.
6	Add subjects into conferences (Rules, Task and Procedures, and Initial Ideas) after training session. Give subjects two days to submit their initial ideas.	Two days
7	Check whether or not subjects have submitted their initial ideas. If subjects have not done so, send email to remind them.	One day before the end of initial idea collection.
8	Add subjects into discussion conferences (Discussion Area, Final Report) after they have submitted the initial ideas. Give subjects ten days to discuss, and one day to finish their group report.	Ten days discussion One day to submit the group report
9	Check whether or not subjects have submitted their group report. Send email to remind subjects about the due date.	One day before the due date
10	Collect final reports by the end of the due date.	
11	Post URLs of the "Post-Questionnaire", "Task Survey", "System Survey". After receiving the group final report, give subjects two days to finish the questionnaires.	Two days
12	Check whether or not subjects have completed the questionnaires. If not, send email to remind them.	One day before the due date
13	Add subjects into debriefing board after they submit the questionnaires.	After questionnaires are submitted

Below are more detailed explanations of the experimental procedures that had been used during the experiment:

1. Subscribe Student Subjects

The instructors were contacted before the new semester started to seek their cooperation. The experiment schedule was worked out along with the course syllabus, alternative assignment, and grading policy with each instructor. Then welcome message was sent to the class introducing the experiment and soliciting for participation. Students were encouraged to volunteer to take the experiment by submitting the Consent Form and Background Questionnaire online.

2. Get Subject Consent Form and Background Questionnaire

Upon receiving a subject's Consent Form and the Background Questionnaire, welcome letters were sent to the subject individually, and the experimental procedures were introduced to the subject via email. A subject list with valid email and other contact information was made. Each subject was assigned an identification code (i.e., subject ID) during his or her online submission of the Consent Form, and the subject identification information was then removed from the following questionnaires, using only the subject ID to identify the subjects thereafter.

3. Access Training Material and Finish Training Task

When all subjects finished their Consent Form and Background Questionnaire, they were randomly assigned into conditions/groups based on the Background Questionnaires. The major factors that were considered during the random grouping include: course number, gender, age, nationality, working experience, and so on, so as to balance the groups and remove any of the effects by these factors.

Separate training topics were created on the toolkit (except for the baseline condition) and training boards on the WebBoard (for all four conditions) for each group. The subjects were put into training conferences where they belonged, where that subjects had a two-day (i.e., 48 hours) training period to make sure they could handle basic functions of the WebBoard and/or the toolkit (List Gathering Tool, Dynamic Voting Tool, or SDSS toolkit). This whole training was conducted asynchronously on the Web. At the end of the training period, training tasks were required to test if the subjects had passed the training session.

4. Finish the Experimental Task

Only after successfully finishing the training session, were the subjects put separately into the experimental boards and/or topics where they belonged and started on the asynchronous group discussion session using the WebBoard and/or the toolkit (List Gathering Tool, Dynamic Voting Tool, or SDSS Toolkit). They received the experimental task and all the instructions for the experiment in their own boards. The subjects had ten days to do the group discussion and finish the task, and one more day to prepare and submit the group final report by the group coordinator.

5. Fill Out the Questionnaires

After finishing the experimental task, the subjects were told the URLs for the "Post-Questionnaire", the "Task Survey" and the "System Survey" on their boards as well as via Email. Subjects had three days to complete the questionnaires online.

6. Debrief Subjects and Subject Grading

Upon receiving the subject's Post-Questionnaire, Task Survey, and System survey, the subject was immediately added into a debriefing conference on the

WebBoard, where he or she could find detailed information about the design and procedures of the experiment, and could discuss the experiment with the investigators (i.e., Zheng Li and Yuanqiong Wang).

Recommended grades for the subjects were given to their instructors promptly upon the completion of the tasks based on the performance of participation and the quality of the group final reports. These grades were only suggested; the instructors decided the final grades.

7. Web-based Questionnaire Management System

This was a truly paperless experiment. All the questionnaires were put online. The researchers (i.e., Zheng Li and Yuanqiong Wang) had also developed a Web-based Questionnaire Management System to manipulate all the experimental data online. The system was password protected on all the critical data so that subjects' confidentiality is well preserved. Since two researchers had been working on the same experiment, the system allowed multiple users to access and manage the experimental data (including monitoring the experimental process) consistently and saved a lot of time and effort.

Compared to the traditional paper based questionnaires, this system (1) could easily update, backup, and store the experimental data in different ways safely; (2) saved labor on data input which tends to introduce human errors; (3) could check the results instantly; and (4) could easily display the results in many ways, such as sorting the data according to different categories (e.g., ID, date, etc.). The development of this online Questionnaire Management System greatly benefited both researchers. Furthermore, with minor improvement, it can be generalized for similar tasks.

6.4 Data Analysis Procedures

After the experiment was finished, two sets of data analysis procedures were applied to analyze the experimental results: (1) Statistical methods were used to analyze the experimental results; (2) Expert teams were formed to judge the quality of decision-making based on the group final reports.

6.4.1 Statistical Analysis

Statistical analysis includes the following procedures, which will be explained in detail in the next chapter (i.e., Chapter 7: Data Analysis and Results):

1. Factor analysis
2. Validation of dependent variables
3. ANOVA analysis

6.4.2 Expert Judgment Procedures

Two teams of expert judges were used to rate or score the quality of decision-making based on group final reports. Team 1 rated the overall quality of group final reports. Six experts from the Department of Information Systems (one faculty, four Ph.D. candidates, and one master student) were invited to be the judges. Team 2 scored the absolute and relative criteria lists collected from group final reports. Four members of the Computing Service Division (CSD), experts on the Computer Purchasing Task at NJIT, were invited as the judges. The procedures, the instructions, and the results of the two teams are discussed below. It was also necessary to validate the results and check the inter-rater reliability after expert judges finished their evaluation.

6.4.2.1 Rating the Quality of Group Final Reports. The expert judges were selected from faculty members and Ph.D. candidates in Information Systems Department at NJIT. It was believed that they were knowledge enough to be the experts with this experimental task. As a result, one faculty member and four Ph.D. candidates were selected. One well-qualified master's student (potential Ph.D. student) also joined the team. They volunteered to evaluate the reports during winter break. Given that having all six expert judges to go through all 33 final reports would be too great a burden, to relieve their workload, the researchers followed the following schema as shown in Table 6.6 below.

In Table 6.6, GID refers to Group ID, RID refers to Report ID, and P1 to P6 refers to the six expert judges. Before presenting the final reports to judgers, a Report ID (RID) was randomly assigned for each report, and then the cover page of each report was removed. The judges only identified the reports with RID instead of GID. For each report, any information concerning the identity of the group was also carefully removed or hidden from the report by the researchers without undermining the content of the report. The purpose of such blind evaluation was to eliminate any possible bias towards certain groups.

In Table 6.6, those cells with "X" or color-coding represent the reports evaluated by a judge. The schema was designed that each report was evaluated by two different judges, and no two judges rated exactly the same set of reports. The purpose of this was to counter balance any possible rater bias.

Table 6.6 Expert Judgment Schema

GID	RID	P1	P2	P3	P4	P5	P6
GLN01	29				X	X	
GLN02	3		X		X		
GLN03	21			X			X
GLN04	8	X					X
GLN05	27		X			X	
GLN10	26	X		X			
GLN11	25	X		X			
GLN12	41			X			X
GLV01	28			X			X
GLV02	38		X		X		
GLV05	10	X	X				
GLV06	12	X		X			
GLV10	31					X	X
GLV11	16	X					X
GLV12	32				X	X	
GLV13	24		X		X		
GNN01	23			X			X
GNN02	19		X		X		
GNN03	22	X					X
GNN04	7	X				X	
GNN05	39		X			X	
GNN06	6				X	X	
GNN07	9			X	X		
GNN10	37	X					X
GNN11	5		X			X	
GNV02	36				X	X	
GNV04	2		X	X			
GNV06	4				X		X
GNV07	13			X			X
GNV10	11	X		X			
GNV11	35				X	X	
GNV12	14		X			X	
GNV13	1	X	X				

Before the evaluation, all judges were required to go through a single training session to make sure they understand the procedures and hold the same standard of judgment. Table 6.7 below shows the guidelines for expert judge training followed during the training session. Table 6.8 shows the Evaluation Form used by the expert judges, and Table 6.9 shows the instructions for expert judges for the quality rating.

Table 6.7 Guidelines for Expert Judge Training

Guidelines for Expert Judge Training

1. All judges will be in the CoLab together for training.
2. We choose three groups' reports from the pilot studies.
3. The "Computer Purchasing Task" and the "Final Report Template" will be distributed to the judges.
4. The judges rating form and instructions will be distributed to the judges and reviewed. The linkages between the task requirements and the rating form will be explained.
5. The judges will read the first report and rate them. After all judges have finished, we will copy each judge's answers to the whiteboard so that everybody can see how others voted. Large discrepancies will be discussed until consensus is reached. (The first report will be a good report)
6. The same procedure will be followed for the second report. (The second report will be a relatively poor report).
7. After each report's rating is discussed, the judging for the two reports will be compared. Judges will then have the opportunity to re-judge each group's report.
8. If time permits, the same procedure will be followed for the third report. (The third report will be an average report).
9. After training session, distribute the reports to judges. The order of the reports will be staggered so that no two judges will judge exactly the same set of reports.

<u>Contents of Judges' packet:</u>

- "Computer Purchasing Task" and "Final Report Template"
- Evaluation Forms (one for each report)
- Instruction for Judges
- Three reports from the pilot study
- 11 reports from the experiment (after training session)

Table 6.8 Expert Judgment Evaluation Form

Evaluation Form

Report ID: ____________________

Instructions: For each of the features below, rate the group's final report on a scale of 1 to 10, with 1 being poor and 10 being excellent.

I. Content of the report

- Absolute Criteria Quality ______________
- Reasons to support Absolute Criteria selection ______________
- Relative Criteria Quality ______________
- Reasons to support Relative Criteria selection ______________
- Quality of Relative Criteria ranking process ______________
- Quality of Relative Criteria ranking orders ______________

II. Presentation format

- Clarity and Completeness ______________

III. Creativity (Originality) ______________

IIII. Overall quality of the report ______________

Table 6.9 Instructions for Expert Judges

Instructions for Expert Judges

I. Content of the report

- **Absolute Criteria Quality:** whether or not the description of each absolute criterion is clear and understandable, and whether the list of the absolute criteria is complete.
- **Reasons to support the Absolute Criteria selection:** whether the reasons for choosing the absolute criteria in the report support their argument.
- **Relative Criteria Quality:** whether or not the description of each relative criterion is clear and understandable, and whether the list of the relative criteria is complete.
- **Reasons to support Relative Criteria selection:** whether the reasons for choosing the relative criteria in the report support their argument.
- **Quality of Relative Criteria ranking orders:** whether the rank orders for the relative criteria are reasonable and whether the reasons for the final ranking of the relative criteria in the report support their argument.

II. Presentation format

- **Clarity and Completeness:** whether the report is clear and well organized, and whether the report included all the required sections.

III. Creativity (Originality): whether the report has any creative/unique ideas.

IIII. Overall quality of the report: Overall, how well the report was written.

The training sessions went about three hours strictly following the guidelines above. After several discussions exposed many differences, all six judges agreed on the standard during training. A month later, all the evaluation forms were collected and all the data were put into a single Excel table. To validate the data, first, SAS was used to look at the distributions of each rater. The results showed that the distributions of each voter were normal. Therefore, the data of individual raters were valid.

Inter-rater reliability is the core issue to be considered. To test the inter-rater reliability, first the data were normalized to remove any possible systematic individual bias. The method was: For each rater, computed the average of each question on all reports the rater evaluated, then removed the average from each data and added 5.5 to that data. Since each report was evaluated twice by two different raters, the two sets of normalized data were compared. If the difference between the two ratings was greater than four, it was considered significantly different. By so doing, it was found that all other data seems fine except two reports yielded big differences between two raters. Therefore, a third person from the six judges was asked to re-evaluate the report and the data set with the smaller difference was kept, and the one with bigger difference was discarded.

6.4.2.2 Scoring the Unique Absolute and Relative Criteria Lists. Four experts from the Computer Service Division (CSD) were invited to score the lists of unique absolute criteria and relative criteria. They were familiar with similar computer purchasing tasks at NJIT, therefore, were well qualified for the evaluation, and no training sessions were held for them.

The researchers (i.e., Zheng Li and Yuanqiong Wang) prepared the two master lists from the group final reports. First, they collected all the absolute and relative criteria lists from all 33 final reports into two separate master lists. After that, with the help of Dr. Murray Turoff, the lists were divided into the following categories (as shown in Table 6.10 below). The duplicates were carefully identified and removed from the lists.

Table 6.10 Summary of Absolute & Relative Criteria Lists

Absolute Category	Number of Unique items	Relative Category	Number of Unique items
RAM	19	Memory	4
Keyboard & Mouse	22	Accessories	17
Monitor	13	Monitor	7
Hard Drive	16	Hard Drive	8
Operating System	15	Software	16
Other Software	17	-	
Processor	33	Processor	10
Service	26	Service	39
Removable Storage	33	Storage	5
Multimedia	31	-	
I/O	35	-	
Cabinet	6	-	
		Reputation	35
		Reliability	14
		Warranty	12
		Delivery	6
		Discounts	5
		Upgrade	10
		Flexibility	10
		Cost & Payment	9
Other	20	Other	22
Total	**286**	**Total**	**229**

The lists were then sent to the four expert judges with two grade scales which define the meanings of A, B, C, D, and F grades for each item in the absolute and relative list (see Table 6.11 and Table 6.12 below). The judges were asked to assign a grade to each item in the lists.

Table 6.11 Scale for Absolute Criteria

Score	Description
A	A necessary minimum requirement valid in the past year and well representing a well specified statement of the requirement.
B	A necessary minimum requirement valid in the past year but not the best possible statement of the requirement in the set of related statements you have.
C	Should be a relative requirement not an absolute (maybe too expensive, and/or not of sufficient value relative to the other necessary requirements.)
D	Poorly states, incomplete, too low performance, or over specified as an absolute requirement
F	Completely wrong, ambiguous, or meaningless.

Table 6.12 Scale for Relative Criteria

Score	Description
A	A nice-to-have feature valid in the past year and well representing a well specified statement of the requirement.
B	A nice-to-have feature valid in the past year but not the best possible statement of the requirement in the set of related statements you have.
C	Should be an absolute requirement not a relative one.
D	Poorly states, incomplete, too low performance, or under specified as a relative requirement
F	Completely wrong, ambiguous, or meaningless.

After collecting the experts' scores on the lists of absolute and relative criteria, a total score was obtained for each report as the quantitative measure of the quality of the report. This data is then analyzed using ANOVA analysis, and the result will be reported in the next chapter.

CHAPTER 7

DATA ANALYSES AND RESULTS

In this chapter, data analyses are discussed based on all the valid data gathered from the 187 individuals who completed the experiment. In Section 7.1, the analyses on the Background Questionnaire are briefly discussed. In Section 7.2, factor analysis and validity of the scales used in the experiment are discussed. Test of the hypotheses proposed in the previous chapter are discussed in Section 7.3. Results from the Task Survey are discussed in Section 7.4. Finally, summary of the hypothesis tests and analysis of the problems encountered during the experiment are discussed in Section 7.5.

7.1 Subject Background Overview

As reported in the previous chapter, students from both undergraduate and graduate levels at NJIT participated in the experiment. A total of 187 students completed the experiment with valid data. A summary of the number of undergraduate and graduate groups for each experimental condition is displayed in Table 7.1.

Table 7.1 Numbers of Undergraduate and Graduate Groups (by Condition)

Conditions		List Gathering Process	
		With List Gathering Tool Support	**Manual**
Dynamic Voting Process	**With HDV Tool Support**	8 groups (4 grads, 4 under) N=44 (24 grads, 20 under)	8 groups (4 grads, 4 under) N= 45 (22 grad, 23 under)
	Manual	8 groups (5 grads, 3 under) N=46 (29 grads, 17 under)	9 groups (7 grads, 2 under) N=52 (42 grads, 10 under)

Based on the Background Questionnaires (see Appendix C), of the experimental population, 34.8% (65) were females and 65.2% (122) were males. As concerns degree, 41.7% (78) of the students majored in either computer science or information systems which comprises the largest portion of the subjects. 36.4% (68) of the students were from the MSIS program. And 10.2% of the subjects were from business or management majors. The distribution of subjects' current degree program is summarized in Figure 7.1 below.

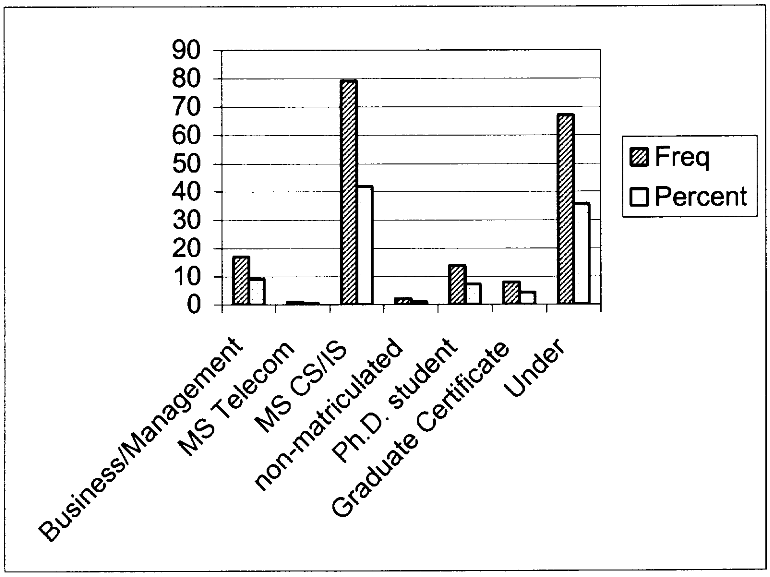


Figure 7.1 Frequency of subjects' current degree program.

The subjects had very diverse ethnic and cultural backgrounds. Of the subjects studied, 46.2% reported that English was their first or native language and 53.8% reported that English was not their native language. Among those subjects who were not born in the U.S., the number of years they had lived in the U.S. was spread fairly evenly from 0 to 27 years. Concerning nationality, 33.7% of the subjects were U.S. citizens, 25.1% were Indian, and 8.0% were Chinese. Individuals from other countries such as Poland, Philippines, Nigeria, Greece, Thailand, Russia, Jordan, etc., were also included. Figure 7.2 shows the distributions of the subjects' ethnic backgrounds.

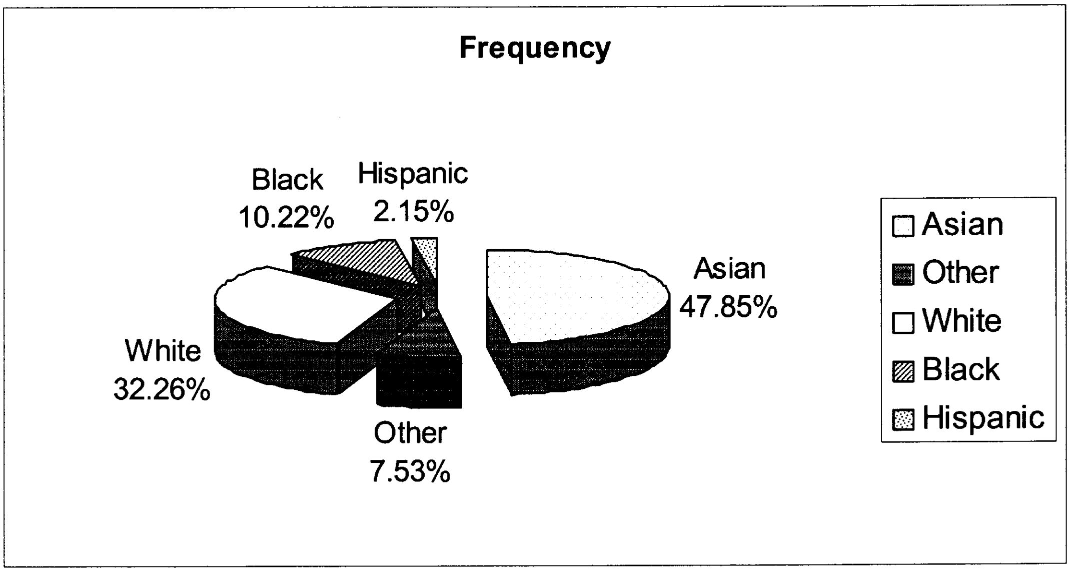


Figure 7.2 Subjects' ethnical background.

Subjects' age ranged from under 23 years to over 40. The majority of the subjects (50.5%) were between 23-30 years of age. The total number of months of full-time employment ranged from 1 to 390 months and is spread fairly evenly, except that there were 15.5% of the subjects who didn't have any previous working experience, and 6.8% of the subjects reported 36 months of full-time employment. Table 7.2 shows the frequency and percentage of subjects' working experience in each category after breaking the number of months into six categories.

Table 7.2 Subjects' Numbers of Months of Fulltime Employment

Months of Employment	Frequency	Percent (%)
0	29	15.5
1-12	36	19.3
13-48	45	24.1
49-120	39	20.9
121-390	27	14.4
Missing	11	5.9

As about the familiarity with WebBoard, the majority of the subjects (73.0%) had previously used the WebBoard frequently. Table 7.3 is the distribution of the WebBoard using experience before the subjects participated in the experiment.

Table 7.3 Subjects' WebBoard Experience

Used WebBoard...	Frequency	Percent (%)
Frequently	136	73.0
Three to ten times	15	8.1
Once or twice	27	14.6
Never	8	4.3

As to how the experimental task related to background information, before participating in the experiment, most subjects (94.1%) reported having the experience of buying a computer. Most of them (70.5%) reported having bought a computer for him/herself. 48.0% of the subjects had bought a computer more than two times. The distribution of subjects' computer purchasing experience is shown in Table 7.4 below:

Table 7.4a Subjects' Computer Purchasing Experience (I)

Bought computer before?	Frequency	Percent (%)
No	11	5.9
Yes	176	94.1

Table 7.4b Subjects' Computer Purchasing Experience (II)

Bought computer for...	Frequency	Percent (%)
Myself	124	70.5
Myself, organization	30	17.1
Myself, organization, other	13	7.4
Myself, other	5	2.8
Organization	3	1.7
Organization, other	1	0.6

Table 7.4c Subjects' Computer Purchasing Experience (III)

Times of computer purchase before...	Frequency	Percent (%)
Once	60	34.3
Twice	31	17.7
More than two times	84	48.0

The above data suggests that there would not be much difference in terms of working experience and computer purchasing experience between groups if subjects were randomly assigned into different groups.

In the self-evaluation part of the Background Questionnaire, most subjects had positive response to the questions. Most subjects (61.6%) reported high or very high confidence in recommending computers. In terms of the confidence level in contributing in a group, 68.7% of the subjects reported high or very high. Most subjects (92.5%)

thought of themselves as average to expert computer users; 98.4% of subjects reported average to very high level group working experience; 79.6% reported average to high or very high level business decision experience; only 11.9% of subjects reported dislike of group discussion; only 16.6% of subjects felt nervous when dealing with new people; 97.9% of subjects had easy access to the WebBoard; 87.1% of subjects were comfortable with group discussion.

All the above findings indicated that the subjects had some previous computer experience and group working experience. Moreover, most subjects had a positive attitude toward group discussion and business decision-making. Therefore, the subjects had the skill to carry out the experimental task. When the subjects were randomly assigned into groups and conditions, all of the above factors were carefully considered and subjects were evenly distributed into groups based on those factors. Therefore, the experimental results shouldn't be biased by any of them. However, when the experiment was conducted in Spring 2002, since the SDSS Toolkit was still under developing and was not ready for the experiment, only baseline condition (with seven groups, 42 graduate student subjects) was tested. But later in Fall 2002, when the SDSS Toolkit was tested, the student body was dramatically changed. Not only the total number of graduate students decreased about 1/3 that resulted in insufficient subjects to subscribe, but the quality of the students also somehow altered. They faced tougher job pressure and seemed not as focused on their studies as previous semesters. As a result, undergraduate students and more graduate students from other courses, who had not been tested by any pilot study, and had practically different expectations and attitudes towards the experiment, had to be included in the experiment. Therefore, The overall distribution of the subjects was actually not even, and bias did exist in this experiment in comparing the subjects' backgrounds of the baseline and the SDSS Toolkit conditions.

7.2 Factor Analysis and Dependent Variable Validation

Most of the dependent variables in this experiment were measured using a composite variable scale, such as perceived quality of decision-making, perceived decision process satisfaction and solution satisfaction, etc. Before summing up all the individual variables into a composite variable, reliability and validity tests – confirmatory factor analysis and Cronbach's Coefficient Alpha using SAS 8.0 – were performed. A composite variable is considered reliable if the Cronbach's Coefficient Alpha was equal to or greater than 0.60 after extracting all the factors. If this is the case, then the values of the individual questions which created the composite scale were summed up and the average value was used as a single one and analyzed. Otherwise, the composite variable was regarded as unreliable, and the questions were analyzed individually.

7.2.1 Factor Analysis

To ensure the uni-dimensionality of the scales, confirmatory factor analysis with Pormax oblique rotation was applied to the Post-Questionnaire (see Appendix F) Question 1 through Question 15, and to all the scales from the expert judgment (team 1) questions (see Table 6.8 Expert Judgment Evaluation Form). This is to eliminate the correlations between the dependent variables.

7.2.1.1 Scales in the Post-Questionnaire. In the Post-Questionnaire, Question 1 to Question 15 were designed to test perceived quality of decision-making, perceived decision process satisfaction and solution satisfaction with multiple questions. Therefore, factor analysis on these questions was performed to test the validity of the scales. Table 7.5 presents the results of the factor loadings of Question 1 through Question 15 after Promax rotation. Based on Table 7.5, two factors were extracted as a result:

- Factor 1: decision process satisfaction which includes Question 3 through Question 9, and Question 13 –> Question {3, 4, 5, 6, 7, 8, 9, 13}
- Factor 2: solution satisfaction which includes Question 2, Question 10 through Question 12, and Question 14 –> Question {2, 10, 11, 12, 14}

The "perceived quality of decision making" index disappeared after the factor analysis. Since the loading of Question 1 was low on both factors, it does not belong to either of the factors. And it will be analyzed separately as the indicator for perceived quality of decision-making. Because of the low loading on Question 15, it was eliminated from further analysis.

Table 7.5 Factor Loadings of Post-Questionnaire (Q1-Q15) After Promax Rotation

Questions	Factor1: Perceived process satisfaction	Factor2: Perceived solution satisfaction
Q1	0.37271	0.35185
Q2	-	0.68426
Q3	0.66837	-
Q4	0.66334	-
Q5	0.85000	-
Q6	0.83770	-
Q7	0.75510	-
Q8	0.76179	-
Q9	0.75121	-
Q10	-	0.58817
Q11	-	0.73278
Q12	-	0.76679
Q13	0.80517	-
Q14	-	0.67813
Q15	-	0.40306

7.2.1.2 Scales on Expert Judgment. There were nine questions in the Expert Judgment Evaluation Form (see Table 6.8) that expert judges used to grade the quality of decision-making based on group final reports. Table 7.6 shows the results of the factor loadings of all these questions after Promax rotation. As a result, only one factor was extracted, which means that all the questions were closely related to each other and measured one single scale – quality.

Table 7.6 Factor Loadings of Expert Judgment Questions After Promax Rotation

Questions	Factor1: Quality of decision-making
CR1	0.81583
CR2	0.88801
CR3	0.87695
CR4	0.90114
CR5	0.69660
CR6	0.85581
Presentation	0.83224
Creativity	0.58065
Overall Quality	0.97570

7.2.2 Validation of Dependent Variables

7.2.2.1 Reliability of the Process Gain (Level of Understanding) Index. In the Post-Questionnaire, Questions 16 through 18 (see Appendix F) were designed to test the level of understanding as a major measure of process gain. The Cronbach Coefficient Alpha of the level of understanding was 0.37, as shown in Table 7.7 below. This was too low to be considered reliable. Correlations between any two of the three questions had also been tested. None of them had Cronbach Coefficient Alpha greater than 0.60. Therefore, the analysis of variance will be based on each individual question.

Table 7.7 Reliability of the Process Gain (Level of Understanding)

Cronbach Coefficient Alpha

Variables	Alpha
Raw	0.32
Standardized	0.33

Cronbach Coefficient Alpha with Deleted Variable

Deleted Variable	Raw Variables		Standardized Variables	
	Correlation with Total	Alpha	Correlation with Total	Alpha
Q16 (Better understand other member's position)	0.261227	0.081059	0.261294	0.081084
Q17 (Uncover valid alternatives)	0.145922	0.320988	0.147816	0.321217
Q18 (Critically re-evaluate the validity of the alternatives)	0.148448	0.312967	0.151677	0.299040

7.2.2.2 Reliability of the Process Loss (Information Overload) Index. In the Post-Questionnaire, Questions 25, 26 and 27 (see Appendix F) were designed to test the information overload as a major measure of process loss. The Cronbach Coefficient Alpha of the level of understanding was 0.63 as shown in Table 7.8 below. Since it is greater than 0.60, the questions in this scale will be summed up and averaged into a composite variable. The analysis of variance for this variable will be conducted to test the significance.

Table 7.8 Reliability of the Process Loss (Information Overload) Scale

Cronbach Coefficient Alpha

Variables	Alpha
Raw	0.63
Standardized	0.63

Cronbach Coefficient Alpha with Deleted Variable

Deleted Variable	Raw Variables		Standardized Variables	
	Correlation with Total	Alpha	Correlation with Total	Alpha
Q25 (System resulted information overload)	0.395990	0.600259	0.392695	0.601135
Q26 (System increased irrelevant information)	0.538613	0.390678	0.539118	0.391707
Q27 (System caused missing information)	0.398544	0.591979	0.399452	0.592035

7.2.2.3 Reliability of the Perceived Solution Satisfaction Index. In the Post-Questionnaire, Questions 2, 10, 11, 12, and 14 (see Appendix F) were designed to test the perceived solution satisfaction as validated by factor analysis. The Cronbach Coefficient Alpha of the solution satisfaction was 0.77 as shown in Table 7.9 below. Since it is greater than 0.60, the questions in this scale will be summed up and averaged into a composite variable. The analysis of variance for this variable will be conducted to test the significance.

Table 7.9 Reliability of the Perceived Solution Satisfaction Scale

Cronbach Coefficient Alpha

Variables	Alpha
Raw	0.77
Standardized	0.77

Cronbach Coefficient Alpha with Deleted Variable

Deleted Variable	Raw Variables: Correlation with Total	Raw Variables: Alpha	Standardized Variables: Correlation with Total	Standardized Variables: Alpha
Q2 (Trivial/Substantial)	0.442737	0.762724	0.441281	0.763543
Q10 (Very dissatisfied/Very satisfied with the quality of solution)	0.590847	0.710491	0.590448	0.713013
Q11 (Extent to reflect your input)	0.512683	0.738223	0.513556	0.739557
Q12 (feeling committed to the group solutions)	0.542985	0.727841	0.545647	0.728609
Q14 (Confident)	0.626860	0.699408	0.626939	0.700039

7.2.2.4 Reliability of the Perceived Process Satisfaction Index. In the Post-Questionnaire, Questions 3, 4, 5, 6, 7, 8, 9, and 13 (see Appendix F) were designed to test the perceived decision process satisfaction as validated by factor analysis. The decision process satisfaction scale is reliable at 0.92 as shown in Table 7.10. Since this scale is reliable, the questions in this scale will be summed up and averaged into a composite variable. The analysis of variance for this variable will be conducted to test the significance.

Table 7.10 Reliability of the Perceived Process Satisfaction Scale

Cronbach Coefficient Alpha

Variables	Alpha
Raw	0.92
Standardized	0.92

Cronbach Coefficient Alpha with Deleted Variable

Deleted Variable	Raw Variables		Standardized Variables	
	Correlation with Total	Alpha	Correlation with Total	Alpha
Q3 (Work Content: Carefully dis./Carelessly dis.)	0.715931	0.906540	0.714074	0.907861
Q4 (Manner: Non-constructive/constructive)	0.683908	0.908910	0.684495	0.910268
Q5 (Efficient/Inefficient)	0.821049	0.897543	0.818467	0.899193
Q6 (Coordinated/Uncoordinated)	0.798613	0.899287	0.801308	0.900636
Q7 (Fair/Unfair)	0.711848	0.906926	0.710487	0.908154
Q8 (Understandable/Confusing)	0.778193	0.901350	0.779808	0.902434
Q9 (Satisfying/Unsatisfying)	0.801788	0.898989	0.803784	0.900428
Q13 (Thoroughly discussed/N)	0.510697	0.924055	0.510349	0.924017

7.2.2.5 Reliability of the Perceived Conflicts Index. In the Post-Questionnaire, Questions 21 through 24 (see Appendix F) were designed to test the perceived level of conflicts. The conflict scale is high at 0.90 as shown in Table 7.11 below. Therefore, the scale was reliable, and the analysis of variance will be based on a composite variable that summed up all the questions in this scale and averaged to test the significance.

Table 7.11 Reliability of the Perceived Conflicts Scale

Cronbach Coefficient Alpha

Variables	Alpha
Raw	0.90
Standardized	0.90

Cronbach Coefficient Alpha with Deleted Variable

Deleted Variable	Raw Variables		Standardized Variables	
	Correlation with Total	Alpha	Correlation with Total	Alpha
Q21 (Feeling conflicts)	0.678904	0.907260	0.684495	0.906128
Q22 (Handle conflicts)	0.813051	0.897543	0.818467	0.900363
Q23 (Acknowledge conflicts)	0.799989	0.899287	0.813735	0.899391
Q24 (Solve conflicts)	0.705634	0.902676	0.709827	0.902154

7.2.2.6 Reliability of the Quality of Decision-making Index. The quality of decision-making scales used by the expert judges (team 1) for assessing the overall quality of the group final reports (see Table 6.8 for the Expert Judgment Evaluation Form) had high a correlation at 0.94 as shown in Table 7.12 below. Therefore, the scale was reliable, and the analysis of variance will be based on a composite variable that summed up all the questions in this scale and averaged to test the significance.

Table 7.12 Reliability of the Quality of Decision-making Scale

Cronbach Coefficient Alpha

Variables	Alpha
Raw	0.94
Standardized	0.94

Cronbach Coefficient Alpha with Deleted Variable

Deleted Variable	Raw Variables Correlation with Total	Raw Variables Alpha	Standardized Variables Correlation with Total	Standardized Variables Alpha
CR1	0.752994	0.931168	0.754455	0.935861
CR2	0.839236	0.926312	0.842009	0.930908
CR3	0.818444	0.927509	0.826268	0.931807
CR4	0.851757	0.925716	0.857169	0.930039
CR5	0.631309	0.942940	0.632166	0.942596
CR6	0.807570	0.927958	0.810784	0.932687
Presentation	0.784180	0.929425	0.785161	0.934137
Creativity	0.517489	0.943323	0.515058	0.948848
Overall Quality	0.969846	0.919395	0.967017	0.923642

7.3 ANOVA Analysis

Before running ANOVA analysis on each variable, a check on the normal distribution of each variable was performed. The ANOVA was conducted only when the values of the variable are normally distributed. If the values of the variable were not normally distributed, data transformation was used to test the normality. If all these efforts failed, a non-parametric ANOVA was then conducted.

7.3.1 Perceived Quality of Decision-making

Since only Question 1 in the Post-Questionnaire was validated as the measure of perceived quality of decision-making after the confirmatory factor analysis, only this question was analyzed using nested ANOVA.

As concerning hypothesis H1, no significant effect was found on this factor.

H1. Groups with SDSS Toolkit support will have higher perceived quality of decision-making than groups without SDSS Toolkit support.

H1a. Groups with Dynamic Voting Tool support will have higher perceived quality of decision-making than groups without Dynamic Voting Tool support.

H1b. Interaction (Synergistic Positive): Groups with both List Gathering Tool and Dynamic Voting Tool (i.e. SDSS Toolkit) support will have disproportionately high perceived quality of decision-making.

Result: H1 (H1a, H1b) was not supported. No difference.

7.3.2 Quality of Decision Making (Expert Judgment)

7.3.2.1 Expert Judgment on Final Report (Overall). As described in the previous chapter (i.e., Section 6.4.2), before doing the analysis on the grades received from the expert judges (team 1), data were standardized to remove any possible bias. Factor analysis validated that all nine questions were measuring the same scale – quality. Therefore, the transformed data were summed up and averaged, and then used for ANOVA analysis. Table 7.13 presents the three-way ANOVA results on the quality of decision-making based on the evaluation of six expert judges on the overall quality of the group final reports.

Table 7.13 Three-way ANOVA on Quality of Decision-making (Overall)

Mean		**List Gathering Process**		**Total**
		With List Gathering Tool Support	**Manual**	
Voting Process	**With HDV Tool Support**	47.57	48.91	48.24
	Manual	41.29	59.04	50.69
Total		44.43	54.27	49.50

Degree	**Quality**
Grad	52.74
Under	44.52

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	7	3586.69491	512.38499	3.65	0.0025
Error	58	8132.66873	140.21843		
Corrected Total	65	11719.36364			

R-Square	**Coeff Var**	**Root MSE**	**Total Qual Mean**
0.306049	23.92199	11.84139	49.50000

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Ltool	1	1237.006238	1237.006238	8.82	**0.0043**
Vtool	1	6.320475	6.320475	0.05	0.8326
Degree	1	637.178144	637.178144	4.54	**0.0373**
LTool*VTool	1	899.789481	899.789481	6.42	**0.0140**
degree*LTool	1	52.194603	52.194603	0.37	0.5442
degree*VTool	1	0.046952	0.046952	0.00	0.9855
degree*LTool*VTool	1	91.033500	91.033500	0.65	0.4237

Three effects were found through the analysis:

- Significant difference between the mean value of groups with the List Gathering Tool support and that of groups without it (p=0.0043). The reports of groups without List Gathering Tool (WebBoard only) had significantly higher quality than groups with it.

- Taken the factor of subjects' degree background into account, significant difference was found between the mean value of graduate groups and that of undergraduate groups (p=0.0373). Reports of those graduate groups had significantly higher quality than those of undergraduate groups.
- Contrary to the hypothesis H2, significant two-way interaction effect (List Gathering Tool x Dynamic Voting Tool, p=0.0140) was found. Reports of those groups without any tool support (WebBoard only) had significantly higher quality than those with the tool support.

As far as hypothesis H2 is concerned, it was not supported.

H2. Groups with SDSS Toolkit support will have higher quality of decision-making than groups without SDSS Toolkit support.

H2a. Groups with Dynamic Voting Tool support will have higher quality of decision-making than groups without Dynamic Voting Tool support.

Result: Not Supported. No difference.

H2b. Interaction (Synergistic Positive): Groups with both List Gathering Tool and Dynamic Voting Tool (i.e. SDSS Toolkit) support will have disproportionately high quality of decision-making.

Result: Not Supported. Significance was found in the reverse direction.

7.3.2.2 Expert Judgment on Final Report (Criteria Lists). In order to judge the quality of the criteria generated by the groups, two master lists were collected from the final reports by the researchers, one for absolute criteria and one for relative criteria. Every item has been assigned a unique number in the list. The master lists were then given to four expert judges from the Computer Services Division (CSD) with the instruction on grading (see Table 6.11 and Table 6.12). Expert judges were asked to assign grades (A, B, C, D, or E) for each criterion in the two lists.

The grades from each judge were collected and input into a database. There were some missing values and inconsistent grades in the grade sheet. The average grade from all the judges was used as the grade for each criterion. The grade for each group was calculated by averaging all the grades for the criteria in its list. Three-way ANOVA analysis was then applied for the two categories – absolute criteria list and relative criteria list. Table 7.14a shows the three-way ANOVA result on the relative criteria.

Table 7.14a Three-way ANOVA on Relative Criteria List

Means

	Relative	**Absolute**
Voting Tool	2.02	1.94
No Voting Tool	2.29	1.95

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	7	1.00484450	0.14354921	0.87	0.5464
Error	24	3.97707274	0.16571136		
Corrected Total	31	4.98191724			

R-Square	**Coeff Var**	**Root MSE**	**Mean**
0.201698	18.79914	0.407077	2.165400

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Degree	1	0.02916237	0.02916237	0.18	0.6786
Ltool	1	0.06473542	0.06473542	0.39	0.5379
Vtool	1	0.67956060	0.67956060	4.10	**0.0541**
Degree*Ltool	1	0.02343643	0.02343643	0.14	0.7102
Degree*Vtool	1	0.14221072	0.14221072	0.86	0.3635
Ltool*Vtool	1	0.14041115	0.14041115	0.85	0.3665
Degree*Ltool*Vtool	1	0.00385891	0.00385891	0.02	0.8800

For relative criteria, there was a significant difference (p=0.0541) between groups with the Dynamic Voting Tool support and groups without it. Contrary to the Hypothesis H2a, the grades of those without Dynamic Voting Tool support were significantly higher than groups with the Dynamic Voting Tool support.

Table 7.14b shows the three-way ANOVA on the absolute criteria list. For absolute criteria, there is a significant interaction effect (p=0.0507) between degree program and presence of the List Gathering Tool. The absolute criteria collected by the undergraduate student groups without List Gathering Tool process had significantly higher quality. As a result, hypothesis H2 (H2a, H2b) was still not supported.

Table 7.14b Three-way ANOVA on Absolute Criteria List

Means		List Gathering Process	
		With List Gathering Tool Support	**Manual**
Degree	**Graduate**	1.98	1.94
	Under	1.75	2.12

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	0.51625091	0.07375013	1.07	0.4087
Error	25	1.71717333	0.06868693		
Corrected Total	32	2.23342424			

R-Square	Coeff Var	Root MSE	Mean
0.231148	13.47570	0.262082	1.944848

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Degree	1	0.00849096	0.00849096	0.12	0.7281
Ltool	1	0.17323638	0.17323638	2.52	0.1248
Vtool	1	0.00178839	0.00178839	0.03	0.8731
Degree*Ltool	1	0.27358457	0.27358457	3.98	**0.0570**
Degree*Vtool	1	0.05255697	0.05255697	0.77	0.3900
Ltool*Vtool	1	0.04508713	0.04508713	0.66	0.4255
Degree*Ltool*Vtool	1	0.04066420	0.04066420	0.59	0.4488

7.3.3 Perceived Satisfaction (Solution, Process)

7.3.3.1 Perceived Solution Satisfaction. Since the scale of solution satisfaction was reliable with the Cronbach's Alpha of greater than 0.60, the values of each individual question were summed up and averaged into a composite variable for ANOVA analysis. Table 7.15 below shows the analysis on the perceived solution satisfaction scale.

Table 7.15 Three-way ANOVA on Perceived Solution Satisfaction

Means		List Gathering Process	
		With List Gathering Tool Support	Manual
Voting Process	With HDV Tool Support	19.51	19.25
	Manual	18.11	19.79

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	91.223967	13.031995	1.02	0.4177
Error	179	2283.845552	12.758914		
Corrected Total	186	2375.069519			

R-Square	Coeff Var	Root MSE	Mean
0.038409	18.61123	3.571962	19.19251

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Degree	1	3.62146310	3.62146310	0.28	0.5949
Ltool	1	25.88201674	25.88201674	2.03	0.1561
Vtool	1	1.59468658	1.59468658	0.12	0.7241
Degree*Ltool	1	51.47440336	51.47440336	4.03	**0.0461**
Degree*Vtool	1	4.44349954	4.44349954	0.35	0.5558
Ltool*Vtool	1	14.78090898	14.78090898	1.16	0.2832
Degree*Ltool*Vtool	1	12.11831633	12.11831633	0.95	0.3311

Taken subjects' degree background into account, there was a significant interaction effect (p=0.0461) between subjects' degree program and the presence of the List Gathering Tool. Subjects who were undergraduate students in manual condition, and graduate students in List Gathering Tool support condition reported significantly higher satisfaction with the solution.

As about the hypothesis H3,

H3. (Perceived solution satisfaction) Groups with SDSS Toolkit support will be more satisfied with their solutions than groups without SDSS Toolkit support.

H3a. Groups with Dynamic Voting Tool support will be more satisfied with their solutions than groups without Dynamic Voting Tool support.

Result: Not Supported. No difference.

H3b. Interaction (Synergistic Positive): Groups with both List Gathering Tool and Dynamic Voting Tool (i.e. SDSS Toolkit) support will be disproportionately more satisfied with their solutions.

Result: Not Supported. No difference.

As a result, hypothesis H3 (H3a, H3b) was not supported.

7.3.3.2 Perceived Process Satisfaction. Since the scale of perceived decision process satisfaction was reliable with the Cronbach's Alpha of greater than 0.60, the values of each individual question were summed up and averaged into a composite variable for ANOVA analysis. Table 7.16 below shows the analysis on decision process satisfaction.

Table 7.16 Three-way ANOVA on Perceived Process Satisfaction

Degree = Graduate

Means		List Gathering Process	
		With List Gathering Tool Support	Manual
Voting Process	With HDV Tool Support	17.96	19.09
	Manual	20.20	20.14

Degree = Undergraduate

Means		List Gathering Process	
		With List Gathering Tool Support	Manual
Voting Process	With HDV Tool Support	20.70	19.70
	Manual	17.47	21.90

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	7	46.4558589	6.6365513	1.44	0.2331
Error	25	115.0318027	4.6012721		
Corrected Total	32	161.4876617			

Source	DF	Type III SS	Mean Square	F Value	Pr> F
LTool	1	9.05099510	9.05099510	1.97	0.1731
VTool	1	2.35594717	2.35594717	0.51	0.4809
LTool*VTool	1	9.64305512	9.64305512	2.10	0.1601
Degree	1	1.35793477	1.35793477	0.30	0.5918
LTool*degree	1	2.16192821	2.16192821	0.47	0.4994
VTool*degree	1	8.12429926	8.12429926	1.77	0.1959
LTool*VTool*degree	1	23.02471866	23.02471866	5.00	**0.0344**

There was no significant difference between groups with tool support and groups without tool support. But when taken the subjects' degree background into account, a significant three-way interaction effect (p=0.0344) was found. The graduate student groups having access to both the List Gathering Tool and the Dynamic Voting Tool reported significantly lower satisfaction toward the decision process (with a mean of

17.96), while the undergraduate students groups having access to neither the List Gathering Tool nor the Dynamic Voting Tool reported significantly higher satisfaction toward the decision process (with a mean of 21.90).

As about hypothesis H4,

H4. (Perceived process satisfaction) Groups with SDSS Toolkit support will be more satisfied with their group process than groups without SDSS Toolkit support.

H4a. Groups with Dynamic Voting Tool support will be more satisfied with their group process than groups without Dynamic Voting Tool support.

Result: Not Supported. No difference.

H4b. Interaction (Synergistic Positive): Groups with both List Gathering Tool and Dynamic Voting Tool (i.e. SDSS Toolkit) support will be disproportionately more satisfied with their group process.

Result: Not Supported. No difference.

As a result, hypothesis H4 (H4a, H4b) was not supported.

7.3.4 Total Comment Length of Group Discussion

A computer program was made available to calculate the length of comments contributed by each group member. For groups without any tool support, the length of comments posted in the group discussion area in the WebBoard was calculated, summed up and then averaged as the length of the contribution of the whole group. The same procedure was carried out for groups with tool support except that for tool support groups the comments counted were those posted in the corresponding toolkit.

Table 7.17 shows the three-way ANOVA result on the total comment length of group discussion.

Table 7.17 Three-way ANOVA on Total Comment Length

<table>
<tr><th colspan="2" rowspan="2">Mean</th><th colspan="2">List Gathering Process</th><th rowspan="2">Total</th></tr>
<tr><th>With List Gathering Tool Support</th><th>Manual</th></tr>
<tr><td rowspan="2">Voting Process</td><td>With HDV Tool Support</td><td>3688.75</td><td>4436.00</td><td>4062.38</td></tr>
<tr><td>Manual</td><td>6232.75</td><td>8190.44</td><td>7269.18</td></tr>
<tr><td colspan="2">Total</td><td>4960.75</td><td>6423.65</td><td>5714.36</td></tr>
</table>

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	136437091.3	19491013.0	2.05	0.0886
Error	25	238047380.3	9521895.2		
Corrected Total	32	374484471.6			

R-Square	Coeff Var	Root MSE	Mean
0.364333	54.00001	3085.757	5714.364

Source	DF	Type III SS	Mean Square	F Value	Pr > F
DEGREE	1	11568565.39	11568565.39	1.21	0.2809
LTOOL	1	4960608.95	4960608.95	0.52	0.4771
VTOOL	1	44698468.59	44698468.59	4.69	**0.0400**
DEGREE*LTOOL	1	6433668.93	6433668.93	0.68	0.4189
DEGREE*VTOOL	1	17479248.32	17479248.32	1.84	0.1876
LTOOL*VTOOL	1	40427.16	40427.16	0.00	0.9486
DEGREE*LTOOL*VTOOL	1	3020392.02	3020392.02	0.32	0.5783

The ANOVA analysis on groups' contribution showed that groups with the Dynamic Voting Tool support made significantly shorter total comments than groups without the Dynamic Voting Tool support (p=0.04).

The coordinators in the groups with the Dynamic Voting Tool support also made significantly shorter total comments than groups without the Dynamic Voting Tool support (p=0.0504). Table 7.18 shows the three-way ANOVA results comparing the total comment length by coordinators.

Table 7.18 Three-way ANOVA on Total Comment Length (Coordinator)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	28692528.35	4098932.62	1.62	0.1757
Error	25	63242166.62	2529686.66		
Corrected Total	32	91934694.97			

R-Square	Coeff Var	Root MSE	TOTALW Mean
0.312097	72.80181	1590.499	2184.697

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LTOOL	1	363153.58	363153.58	0.14	0.7080
VTOOL	1	10686871.05	10686871.05	4.22	**0.0504**
LTOOL*VTOOL	1	115577.64	115577.64	0.05	0.8325
DEGREE	1	3723757.68	3723757.68	1.47	0.2364
LTOOL*DEGREE	1	982620.80	982620.80	0.39	0.5388
VTOOL*DEGREE	1	4002169.46	4002169.46	1.58	0.2201
LTOOL*VTOOL*DEGREE	1	482012.72	482012.72	0.19	0.6662

As concerning hypothesis H5,

H5. (Comment length) Groups with SDSS Toolkit support will have shorter comments than groups without SDSS Toolkit support.

H5a. Groups with Dynamic Voting Tool support will have shorter comments than groups without Dynamic Voting Tool support.

Result: supported.

H5b. Interaction (Synergistic Positive): Groups with both List Gathering Tool and Dynamic Voting Tool (i.e., SDSS Toolkit) support will have disproportionately short comments.

Result: Not supported. No difference.

As a result, H5a was supported, but H5b was not supported. For H5b, no difference was found. And for hypothesis H7, H7. Coordinators in groups with Dynamic Voting Tool support will have shorter comments than coordinators in groups without Dynamic Voting Tool support.

As a result, H7 was supported.

The ANOVA analysis between the length of comments by individual group member and that by coordinators showed a significant difference ($p<0.0001$) as Table 7.19 shows. The coordinators made significantly longer comments than other group members. So concerning hypothesis H8,

H8. Group coordinators will have longer comments than other group members.

As a result, hypothesis H8 was supported.

Table 7.19 One-way ANOVA on Total Comment Length (Role)

Means

Role	Comment Length
Coordinator	2295.39
Member	737.42

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	65888573.9	65888537.9	73.56	< .0001
Error	184	164814087.3	895728.7		
Corrected Total	185	2307.2661.2			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
ROLE	1	65888573.90	65888573.90	73.56	< .0001

Taking the degree program into account, some interaction effects were also found with the role of coordinator vs. members and the subjects' degree background.

- The coordinators in graduate student groups made the longest comments (in total), while the members in undergraduate student groups made the shortest comments as shown in Table 7.20.

- Individual postings in the List Gathering Tool supported groups were significantly shorter than that in groups without the List Gathering Tool support as shown in Table 7.21.
- When analyzing the data from graduate and undergraduate groups separately, it was found that the coordinators in graduate groups without any tool support made the longest comments, groups with the List Gathering Tool support made significantly shorter comments, groups with the Dynamic Voting Tool support also made significantly shorter comments; while in undergraduate groups, only the role of the member (coordinator vs. member) had a significant effect (see Table 7.22).

Table 7.20 Two-way ANOVA on Total Comment Length (Degree x Role)

Means		Role		Total
		Coordinator	**Member**	
Degree	**Graduate**	2694.80	781.66	1111.51
	Under	1680.92	662.93	851.99
Total		2295.39	737.42	1013.84

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	3	74491683.7	24830561.2	28.93	**< .0001**
Error	182	156210977.5	858302.1		
Corrected Total	185	230702661.2			

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Degree	1	8282286.30	8282286.30	9.65	0.0022
Role	1	55471101.83	55471101.83	64.63	**< .0001**
Role * Degree	1	5173526.42	5173526.42	6.03	0.0150

Table 7.21 Three-way ANOVA on Total Comment Length (List x Voting x Role)

Coordinator

Mean		List Gathering Process		Total
		With List Gathering Tool Support	Manual	
Voting Process	With HDV Tool Support	1229.63	2033.88	1631.75
	Manual	2728.13	3090.56	2920.00
Total		1978.88	2593.29	2295.39

Member

Mean		List Gathering Process		Total
		With List Gathering Tool Support	Manual	
Voting Process	With HDV Tool Support	546.47	533.81	540.14
	Manual	737.82	1067.42	912.79
Total		644.73	824.25	737.42

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	90198988.5	1285569.8	16.32	**< .0001**
Error	178	140503672.6	789346.5		
Corrected Total	185	230702661.2			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
List	1	3722895.89	3722895.89	4.72	0.0312
Role	1	74947234.03	64946234.03	82.28	**< .0001**
VTool	1	18197908.37	18197908.37	23.05	**< .0001**
LTool*Role	1	1221276.76	1221276.76	1.55	0.2152
LTool*Vtool	1	16761.76	16761.76	0.02	0.8843
VTool*Role	1	5665600.21	5665600.21	7.18	0.0081
LTool*VTool*Role	1	1039843.79	1039843.79	1.32	0.2526

Table 7.22 Three-way ANOVA on Total Comment Length (a)

(a) Graduate: List x Voting x Role

Coordinator

Mean		List Gathering Process		Total
		With List Gathering Tool Support	**Manual**	
Voting Process	**With HDV Tool Support**	905.75	2515.25	1710.50
	Manual	3230.60	3437.00	3351.00
Total		2197.33	3101.82	2694.80

Member

Mean		List Gathering Process		Total
		With List Gathering Tool Support	**Manual**	
Voting Process	**With HDV Tool Support**	498.40	452.76	477.43
	Manual	720.75	1145.03	972.44
Total		619.68	917.71	781.66

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	7	86958443.0	12422634.7	13.43	**< .0001**
Error	178	99867756.0	924701.4		
Corrected Total	185	186826199.0			

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
List	1	4712723.11	4712723.11	5.10	0.0260
Role	1	51742851.95	51742851.95	55.96	**< .0001**
VTool	1	16944302.60	16944302.60	18.32	**< .0001**
LTool*Role	1	2021400.28	2021400.28	2.19	0.1422
LTool*Vtool	1	852158.11	852158.11	0.92	0.3392
VTool*Role	1	5321518.21	5321518.21	5.75	0.0182
LTool*VTool*Role	1	3432935.23	3432935.23	3.71	0.0566

Table 7.22 Three-way ANOVA on Total Comment Length (b)

(b) Undergraduate: List x Voting x Role

Coordinator

Mean		List Gathering Process		Total
		With List Gathering Tool Support	Manual	
Voting Process	With HDV Tool Support	1553.50	1552.50	1553.00
	Manual	1890.67	1878.00	1885.60
Total		1698.00	1661.00	1680.92

Member

Mean		List Gathering Process		Total
		With List Gathering Tool Support	Manual	
Voting Process	With HDV Tool Support	606.56	606.32	606.43
	Manual	767.07	727.88	752.82
Total		681.47	642.33	662.93

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	11607970.47	1658281.50	3.50	0.0031
Error	178	29328172.51	473035.04		
Corrected Total	185	40936142.99			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
List	1	1714.79	1714.79	0.00	0.9522
Role	1	10555438.39	10555438.39	22.31	**<.0001**
VTool	1	542602.83	542602.83	1.15	0.2883
LTool*Role	1	403.93	403.93	0.00	0.9768
LTool*Vtool	1	1557.56	1557.56	0.00	0.9544
VTool*Role	1	88063.60	88063.60	0.19	0.6676
LTool*VTool*Role	1	452.53	452.53	0.00	.09754

7.3.5 Degree of Participation

For each group, as described in the previous section, each member's contribution was calculated by a software program. The degree of participation was calculated using the standard deviation of members' percentaged word counts. The ANOVA result of the degree of participation is shown in Table 7.23 below.

Table 7.23 Three-way ANOVA on Degree of Participation

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	0.03825361	0.00546480	1.05	0.4248
Error	25	0.13047642	0.00521906		
Corrected Total	32	0.16873003			

R-Square	Coeff Var	Root MSE	Mean
0.226715	43.74434	0.072243	0.165148

Source	DF	Type III SS	Mean Square	F Value	Pr > F
DEGREE	1	0.00001798	0.00001798	0.00	0.9537
LTOOL	1	0.01489547	0.01489547	2.85	0.1036
VTOOL	1	0.00801743	0.00801743	1.54	0.2267
DEGREE*LTOOL	1	0.00013697	0.00013697	0.03	0.8726
DEGREE*VTOOL	1	0.00182442	0.00182442	0.35	0.5597
LTOOL*VTOOL	1	0.00180632	0.00180632	0.35	0.5616
DEGREE*LTOOL*VTOOL	1	0.00880828	0.00880828	1.69	0.2058

ANOVA result shows that there was no significant difference between the groups with tool support and the groups without the tool support in terms of the degree of participation. As concerning hypothesis H6,

H6. (Degree of participation) Groups with SDSS Toolkit support will have less degree of participation than groups without SDSS Toolkit support.

H6a. Groups with Dynamic Voting Tool support will have less degree of participation than groups without Dynamic Voting Tool support.

H6b. Interaction (Synergistic Positive): Groups with both List Gathering Tool and Dynamic Voting Tool (i.e., SDSS Toolkit) support will have disproportionately less degree of participation.

As a result, H6 (H6a, H6b) was not supported. No difference was found.

7.4 Analysis of Task Survey

After subjects completed the experimental task, a Task Survey and a System Survey were distributed along with the Post-Questionnaire. The results of the System Survey are discussed in Chapter 5. In this section, the results of the Task Survey are discussed as a post-task checkup.

There were ten five-point semantic differential questions in the Task Survey (see Appendix D). Overall, subjects reported that they needed a little more than average effort, with an average of 3.29, to finish the task, in which 37.8% of the subjects thought they needed a lot of effort. This suggested that the experimental task was not an easy task. When comparing the means between the undergraduate and graduate groups, the undergraduate groups reported significantly more effort. Table 7.24 shows the ANOVA result comparing the means between graduate and undergraduate groups.

Three-way ANOVA was used to further analyze the data. *The result indicated that the groups without any tool support reported that they needed significantly more effort to carry out the task.* This suggests that the toolkit to some extent reduced the effort needed to carry out the task. Table 7.25 shows the three-way ANOVA result.

Table 7.24 One-way ANOVA on Effort Needed to Finish the Task

Means

Graduate	3.19
Under graduate	3.46

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	1	3.35	3.35	5.29	0.02
Error	185	117.06	0.63		
Corrected	Total	186	120.41		

Source	DF	Type III SS	Mean Square	F Value	Pr> F
Degree	1	3.35	3.35	5.29	0.02

Table 7.25 Three-way ANOVA on Effort Needed to Finish the Task

Means		List Gathering Process	
		With List Gathering Tool Support	Manual
Voting Process	With HDV Tool Support	3.35	3.11
	Manual	3.28	3.40

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	7	9.64	1.38	2.23	0.03
Error	179	110.76	0.62		
Corrected Total	186	120.41			

Source	DF	Type III SS	Mean Square	F Value	Pr> F
Degree	1	4.91	4.91	7.93	0.01
LTool	1	0.00	0.00	0.00	0.99
VTool	1	1.65	1.65	2.67	0.10
Degree*LTool	1	2.05	2.05	3.32	0.07
Degree*VTool	1	0.00	0.00	0.00	0.99
LTool*VTool	1	2.47	2.47	3.98	0.05
Degree* LTool*VTool	1	0.30	0.30	0.49	0.48

However, in terms of difficulty of the task, subjects reported an average of 2.81, which means they didn't think that the task was difficult to them as an individual. This indicated that most subjects had underestimated the task.

When the subjects were asked, "To what degree do you think the task was interesting and motivating to you", with an average of 3.49, they thought that the task was somewhat interesting.

A majority of subjects (91.5%) thought completing the task was important to critical to them. This can be explained because the subjects needed to finish the task to get course credits. They seemed to have enjoyed the task (mean = 3.18, Not enjoy 1 2 3 4 5 Enjoy) and thought there was enough information (mean = 2.18, Definitely 1 2 3 4 5 Not at all) provided for them to carry out the task. They also thought the task description was pretty clear with an average of 3.81 (Unclear 1 2 3 4 5 Clear).

As to the knowledge necessary for the task, the subjects seemed to be very confident with themselves. The average of 3.74 indicated that they thought they have enough background experience/knowledge that was needed to finish the task. 92% of the subjects reported that they had to have some extent to a very great extent of background knowledge.

In response to the question "Was there an understandable approach that could be followed in doing your contributions to the task", 84% of the subjects gave a positive answer.

In summary, the results of the Task Survey indicted that subjects were pretty confident in doing the task, but they might have underestimated the difficulty of the task; and there was a clear defined approach for the subjects to follow in carrying out the task.

7.5 Discussion of Results

7.5.1 Results of Hypotheses Tests

Although the System Survey yielded very encouraging evaluations towards the Toolkit, and the Task Survey reflected positive attitudes towards the experiment and the toolkit, statistical data analysis showed that most of the hypotheses were not supported, and only several positive significant results were found concerning the contributions in terms of comment length (H5a), and the coordinator role (H7, H8). Table 7.26 below shows the summaries of the hypotheses tests. In this section, explanations are given to this result.

Table 7.26 Summary of Hypotheses Tests

Dependent Variables	Hypotheses	Significant	Supported
H1. (Perceived quality of decision-making) Groups with SDSS Toolkit support will have higher perceived quality of decision-making than groups without SDSS Toolkit support.	H1a. Groups with Dynamic Voting Tool support will have higher perceived quality of decision-making than groups without Dynamic Voting Tool support.	No	No difference
	H1b. Interaction (Synergistic Positive): Groups with both List Gathering Tool and Dynamic Voting Tool (i.e., SDSS Toolkit) support will have disproportionately high perceived quality of decision-making.	No	No difference
H2. (Quality of decision-making) Groups with SDSS Toolkit support will have higher quality of decision-making than groups without SDSS Toolkit support.	H2a. Groups with Dynamic Voting Tool support will have higher quality of decision-making than groups without Dynamic Voting Tool support.	Yes (P=0.0507) (By team 2)	No, in the reverse direction
	H2b. Interaction (Synergistic Positive): Groups with both List Gathering Tool and Dynamic Voting Tool (i.e., SDSS Toolkit) support will have disproportionately high quality of decision-making.	Yes (P=0.0140) (By team 1)	No, in the reverse direction

Table 7.26 Summary of Hypotheses Tests (Continued)

Dependent Variables	Hypotheses	Significant	Supported
H3. (Perceived solution satisfaction) Groups with SDSS Toolkit support will be more satisfied with their solutions than groups without SDSS Toolkit support.	H3a. Groups with Dynamic Voting Tool support will be more satisfied with their solutions than groups without Dynamic Voting Tool support.	No	No difference
	H3b. Interaction (Synergistic Positive): Groups with both List Gathering Tool and Dynamic Voting Tool (i.e., SDSS Toolkit) support will be disproportionately more satisfied with their solutions.	No	No difference
H4. (Perceived process satisfaction) Groups with SDSS Toolkit support will be more satisfied with their group process than groups without SDSS Toolkit support.	H4a. Groups with Dynamic Voting Tool support will be more satisfied with their group process than groups without Dynamic Voting Tool support.	No	No difference
	H4b. Interaction (Synergistic Positive): Groups with both List Gathering Tool and Dynamic Voting Tool (i.e., SDSS Toolkit) support will be disproportionately more satisfied with their group process.	No	No difference
H5. (Comment length) Groups with SDSS Toolkit support will have shorter comments than groups without SDSS Toolkit support.	H5a. Groups with Dynamic Voting Tool support will have shorter comments than groups without Dynamic Voting Tool support.	Yes (P=0.0400)	Yes
	H5b. Interaction (Synergistic Positive): Groups with both List Gathering Tool and Dynamic Voting Tool (i.e., SDSS Toolkit) support will have disproportionately short comments.	No	No difference
H6. (Degree of participation) Groups with SDSS Toolkit support will have less degree of participation than groups without SDSS Toolkit support.	H6a. Groups with Dynamic Voting Tool support will have less degree of participation than groups without Dynamic Voting Tool support.	No	No difference
	H6b. Interaction (Synergistic Positive): Groups with both List Gathering Tool and Dynamic Voting Tool (i.e., SDSS Toolkit) support will have disproportionately less degree of participation.	No	No difference
H7. Coordinator with Voting Tool	H7. Coordinators in groups with Dynamic Voting Tool support will have shorter comments than coordinators in groups without Dynamic Voting Tool support.	Yes (P=0.0504)	Yes
H8. Coordinator' participation	H8. Group coordinators will have longer comments than other group members.	Yes (P < 0.0001)	Yes

One explanation for the results of the hypotheses tests was that the SDSS toolkit was somewhat complex and not very easy to understand given a relative short period of time. Since most of the students were already very familiar with the WebBoard conferencing system, which they frequently use for their regular courses, their mental models were more likely to accept the structures of that system. The SDSS toolkit designed and developed by the researchers was not exactly the same as the one in their mental model, and it might take a longer time for subjects to adapt this system. With a limited time and very intense schedule of the experiment, the subjects might not have had enough time to get as familiar to the system as they were with the WebBoard. Therefore, compared to the baseline condition (i.e., WebBoard only), hypotheses H1, H3, H4, and H6 yielded no difference, and H2 even yielded significantly reverse effects. In terms of the quality of decision-making, it was found that groups without any tool support had the highest quality in the group final reports, where graduate student groups had higher quality than undergraduate student groups.

Although the experimental conditions 1, 2, and 3 were intended to use the tool (SDSS Toolkit, Dynamic Voting Tool, or List Gathering Tool) plus the WebBoard, it turned out that for the List Gathering Tool and SDSS Toolkit conditions, the experimental task was mainly carried out using the toolkit only, and the WebBoard was only used for training and instruction postings, which turned out to be a major distract rather than complement. Therefore, in a way, this experiment was in fact designed to compare the SDSS Toolkit with the WebBoard conferencing system, which was a very nice piece of commercial software. Looking back, this may not be a wise choice. Even if a conference system were needed as baseline condition, it should be as fresh to the subjects as the SDSS Toolkit, so that the degree of familiarity could be at the same level. And the subjects would not have any cognitive inclination in advance.

As discussed in the Section 7.1, the subjects had diverse backgrounds. Although they were randomly assigned into different treatment groups, it was interesting to see whether the subjects' previous working experience had any confounding effect. However, no significant correlation was found between subjects' previous working experience and their response to the Post-Questionnaire.

From the observation of the group process during the experiment, there was a noticeable difference between students from different courses. For example, most students from a graduate IS core course worked much harder – they spent more time on the system (in terms of times they logged into the system, the items and comments they posted) – while students from a MIS course tended to be inactive. Many of then just disappear for several days and then came back at the last minute. The course effect was checked, but no significant difference was found when comparing the means of the responses among students from different courses.

However, this could still be a major factor that affected the result. During pilot studies, only students from two Information Systems core courses (i.e., CIS677, CIS 675) were participated. Compared to their tough course work, the experimental task was relatively easier and more interesting, and they tended to work harder on the assignment in order to get a better grade. Same was true for the experiment run on Spring 2002 with the seven baseline condition groups. When more courses were included in the experiment in Fall 2002, especially undergraduate students were included (which had not been tested by pilot studies), many unexpected factors were introduced as well. The students from other courses, especially from MIS courses, had noticeably difference attitudes and expectations towards the experiment. Besides, due to the economics and other political influences during Fall 2002, the students' overall performance were not as good as before. All the above, in general, negatively affected the experimental result. Looking back, it was found that it was not a good choice to run the seven baseline condition groups in Spring 2002 and run the tool condition groups in Fall 2002. In the future, the experimental conditions should be fairly distributed along the time line.

Since both graduate and undergraduate students were used in the experiment, the effects of the degree were checked. These were not hypotheses that this dissertation intended to test, but the findings may help the researchers uncover the patterns of the degree effects. The analysis of the effects of the degree program indicated that the degree the subjects were working on did play a role in the subjects' perception. For example, the graduate student groups with the List Gathering Tool support had significantly higher satisfaction toward their solution, and undergraduate student groups without tool support reported significantly higher satisfaction toward decision process. This seems to indicate that graduate students tend to appreciate the tool more than undergraduate students.

One of the reasons for this result might be that many of the graduate students who participated in the experiment were MSIS students who were likely to have been exposed to the Delphi process through one of their core courses. Therefore, they were more likely to understand the process used in the experiment.

Although the Dynamic Voting Tool supported groups had the shortest comments, the groups with supports of "both tools" did have shorter comments overall. Comparing the mean length of comments among all the conditions, groups without any tool support had the longest comments. This seems to show that the tools did help groups focus on the task and helped reduce the duplications during the discussion. An analysis on the correlation between the comment length and the decision quality did not abtain any significant result. Therefore, it seemed that the tools helped reduce some workload while keeping the quality of the group work.

The result that coordinators had posted significantly more comments than the regular group members can be explained by the extra work done by the coordinators. During the experiment, the coordinators need to coordinate all the works within their groups. For the voting process, the coordinators need to decide when to vote, request the vote and remind all the members to start a voting session. Therefore, they tended to post more and longer messages than other group members did.

7.5.2 Problems Encountered During the Experiment

Even though several rounds of pilot study were exploited before the formal experiment, some new problems still appeared during the main study. In this section, some problems encountered during the experiment are discussed.

7.5.2.1 Ethics Issues. During the experiment, all the group interactions were online and mainly using the conferencing system (i.e., WebBoard) and the toolkit. No emails, phones, or online chats between members were allowed. The researchers used emails and WebBoard to contact the subjects and informed them of the procedures. Email reminders were sent at the start and end of each step in order to keep the subjects in track. It was astonishing to find that one subject thought the researchers were using emails to *harass* him.

At the beginning of the experiment, the subjects were required to introduce themselves and try to elect one coordinator for their group. If they failed to choose a coordinator for their group, the experimenter would randomly assign one for them, and posted a message in the WebBoard confirming the name of the coordinator by the deadline. One of the subjects who was nominated by group members did not want to accept the position, and he sent the following email to the researchers:

> I did not volunteer. How can you let someone volunteer me? I suggest that you make the person who volunteered me be coordinator. How would you feel if this was done to you? It's not the extra effort, it is the method in which I was railroaded into this that bothers me. Is this in line with NJIT view of ethical behavior? ...... I don't want to be Group Leader because of the underhanded way that I was 'elected'. ...... One student singled me out and the other two chimed in to ensure that they wouldn't have the extra work.

He then sent out several other emails to other group members indicating that he didn't want to be the coordinator. Since he had spread negative feelings about the experiment among his gorup, the researchers had to rearrange him to another group to continue the experiment.

Ethical issues are always one of the most important issues when conducting such kind of research. At first, the researchers didn't realize that this problem was an ethical issue, since it was clearly stated in the instructions that the coordinator would be assigned randomly in case the group didn't have one by the deadline. After discussing with the advisors, the researchers realized that subjects should not be forced to be the coordinator or do any other tasks. This kind of issues should be considered in the future experiment.

7.5.2.2 Lack of Active Participation. Overall, the participation was much more poor at Fall 2002 than before due to the following reasons.

Low expectation: To encourage active participation, student subjects were given 10%~20% course credits to participate in the experiment. An alternative task was assigned for the students if they chose not to participate in the experiment or quit. Although it was designed that the effort required for both the experiment and the alternative task were almost the same, It was observed that during Fall 2002, most students expected less effort in the experiment when entered.

Bad timing: The experiment was running around the period of mid-term exams. Many student subjects with four or five courses were busy dealing with the exam. Therefore, some students didn't actively participate in the group discussion and put in very little effort.

Poor attitude: Some of the students just posted one or two items in the group working area at the beginning of the experiment and thought that they had finished the task. Instead of following the instruction that requires everyday activity on the system, some students thought that the task only required one time contribution. For instance, one of the subjects posted one comments on the system and said, "*I think we have done*". Another subjects didn't have any activity after logging onto the experimental system. He was thought to have dropped out from the experiment. However, during the last night of the experiment, he posted 46 comments onto the system, and most of his comments were simply "*Yes, I agree*" or "*No*". Although the researchers sent emails to remind the subjects of such behaviors, overall, the participation was poor. And such poor behaviors had seriously undermined the experimental result.

7.5.2.3 Drop Outs. There were high dropouts during the experiment due to the following reasons.

Behind the schedule: A set of pre-defined procedures was set for the experiment. The subjects needed to finish each step within a certain period of time before they were allowed to enter the next one during the experiment. Some subjects had to be removed from the experiment by the researchers because they didn't finish the required task on time.

Withdrew the course: Since the experiment started one day before the last day to withdraw from a course at NJIT, some students withdrew from the course and wasn't able to continue the experiment.

To reduce the dropouts, the researchers had tried to send emails one day before the deadline of each step to remind the subjects about the experimental schedule. However, since some steps were only two days apart, the subjects might have been overwhelmed by the emails and it turned out to be ineffective.

7.5.2.3 Training. In order to prepare subjects for the experimental system and task, a standard training website was developed by the researchers for each experimental condition (WebBoard, Dynamic Voting Tool, List Gathering Tool, SDSS Toolkit). It included a set of mini-lessons on how to use the corresponding software system and a set of training tasks as exercises. Successfully completing the training tasks indicated that one had learned the basic features of the system which will be used for the experimental task.

Most subjects finished all the training tasks online within the deadline. Unfortunately, some of them underestimated the difficulty of the system and the task.

Since most of the subjects did have extensive experience in using the computer systems, they tended not to go through the tutorial step by step. Instead, they used a trial and error method to finish the training tasks. Moreover, they didn't regard the training task as a warm up for doing the real experiment task. Instead, they simply wanted to finish it and get over with it. As a result, some of the subjects didn't really master the system before they started the experimental task.

Comments from the System Survey also indicated that subjects didn't realize the importance of the training. Even though they finished the tasks, they still did not know how to use many of the various features of the toolkit in the experiment.

Since this experiment was designed to test the effects of the toolkit, a thorough understanding and full control of the toolkit is very critical to the final tests. In this experiment, the training period (two days) was relatively short for such a complex new toolkit. Furthermore, since the training was conducted online, it was lack the way to ensure that the subjects were really achieved the goal. Therefore, the subjects might not be really prepared for the task by using the toolkit.

The unfamiliarity to the SDSS system could be one of the most important reasons why the results from the toolkit supported groups were no better than the results from the groups without tool support. To make the training more effective, a face-to-face training session may adopt if possible in the future research.

7.5.2.4 Mixed With Other Experiments. Since there were several other similar experiments running at NJIT during the same time period this experiment was running, some subjects participated in other different experiments besides this one. All the experiments used WebBoard as one of the communication systems, the training for using the WebBoard and the training tasks were similar. But these WebBoards and the experimental system (i.e., the toolkit) were on different servers and had different URLs. This caused some extra trouble and confusion among subjects. For example, one subjects thought he had finished all the WebBoard training tasks while in fact it was for another experiment. Fortunately, the two experiments were running on different servers, and this problem was easily identified.

Some subjects couldn't focus on this experiment by dealing with several different URLs and instructions at the same time. This was also one important reason why the result was not good. To resolve the conflict, future research should use different time slots for different experiments within one organization. Or the number of similar experiments one subject can take at the same time should be limited.

7.5.2.5 Time Period. In the Task Survey, some subjects expressed that they would like to have more time to carry out the experimental task.

This experiment lasted about three weeks, in which ten days for group discussion and one day for report writing. According to the experimental procedure, subjects needed to propose all the items they could think of and organize them into a list, then vote on the list; based on the voting result, they could modify the list and discuss again until they reached a group decision. They should be able to do several rounds of discussion and voting to finalize the group decision. Nevertheless, most groups only had time to vote on the list once. One of the reasons for this was that group members tended to regard voting as the last step of the group discussion and they tended to put the voting session off to the last day of the experiment. Moreover, due to the nature of asynchronous communication, delay was expected during the group discussion and voting process. For groups that tried several rounds of voting, often times, there were only one or two people who voted before the voting deadline was passed. In this case, they had to restart a new voting session to let other group member vote.

The idea of Human Dynamic Voting during decision-making is new, and the subjects need more training to understand the concept. More training on the concept of the SDSS system might be needed in this case. For the relatively complex procedures as held in this experiment, more time for carrying out the task is also needed given the delay of asynchronous communication. However, the dropout rate might have been even worse if the experimental period lasted longer. Doing a field trial of the system, which uses the system to do a real world task, might be a solution to this dilemma.

7.5.2.6 System Performance In the System Survey, some of the subjects complained that the idea of suggesting and voting on the modification caused confusion, and the system should provide a mechanism that allows comments and replies. This was due to the fact that subjects were very familiar with the WebBoard conferencing system. As a matter of fact, this system was not designed as a conferencing system. Ideally, the List Gathering Tool should be used within another conferencing system to help group members better organize their ideas. But in this experiment, in order to push the subjects to use the SDSS system, the subjects were not allowed to use any other communication system to do the group discussion in the List Gathering Tool support and SDSS Toolkit support condition.

Since some subjects had already got used to the conferencing system, they could hardly adapt the new system and focus on the task in such a short period of time. This might have hindered their performance on the task.

Some subjects also reported that the system was slow when there were many items in the list. This was the problem of system design and one disadvantage of ColdFusion5. The code should be optimized and better algorithm should be adopted to improve speed in the future.

CHAPTER 8

FIELD STUDIES

This chapter presents several case studies of using the Web-based collaborative Social Decision Support System (SDSS) Toolkit by students in graduate level courses at New Jersey Institute of Technology (NJIT) to assess what they had learned together. The students were asked to collectively pool their interpretations of what they learned and see to what degree they had a consensus on the importance of topics covered in the course. The evaluation process and results are presented in this chapter as a case study on how such a toolkit can be used in a collaborative learning environment. In the conclusion, possible enhancements and the future use of the toolkit as a learning tool are discussed. These case studies were conducted by Zheng Li and Yuanqiong Wang together using the List Gathering Tool combined with the Dynamic Voting Tool. Therefore, they reported the results together (Wang et al., 2003).

8.1 Introduction

Collaboration among students in online courses as well as face-to-face courses enriches the learning experience, enhances the exchange of knowledge, and transforms a potentially solitary existence into an interactive journey (Benbunan-Fich, 2002; Hiltz, 1994; Lazarus, 2002; Leidner and Jarvenpaa, 1995). A useful collaborative learning tool will allow a class to engage in a structured discussion on a particular issue (Clark, 2000; Harasim et al, 1995; Turoff et al, 1995). Furthermore, a Web-based system gives great flexibility for both in-class teaching and distance learning. Web-based Social Decision Support System (SDSS) Toolkit, developed by Zheng Li and Yuanqiong Wang, can support collaborative learning activities. This system has been used to poll students opinions on achieved course objectives in several graduate courses at New Jersey Institute of Technology. This chapter describes three case studies of this exercise.

Evaluating whether the teaching objectives have been met at the end of the course can help the instructors to improve their teaching, and help the students to review the course material, hence further understand the course subject. Such an end-of-course exercise is itself a form of computer-mediated collaborative learning (Alavi, 1994). Most course evaluations have been focused on the instructor's teaching behaviors, such as being an organized presenter of information or being fair-minded in grading, and the students' performance. And often times, the evaluation on the instructor's ability was based on a standard student survey questionnaire, either paper-based (Achtemeier, et al 2003; Hmieleski, 2000; Hmieleski, et al 2000) or online survey, while the evaluation on the students' perceptions was based on a final exam at the end of the semester. However, very few prior studies were found that compared the teaching objectives and students' perceptions of the course contents. According to Brown and his colleagues (1989), the gap between the client experiences and professional perceptions of client experiences will highly influence clients' evaluation on the service. Therefore, finding the gap between students' perceptions and instructors' teaching objectives can help teaching staff to improve their teaching.

Since Spring 2002, Li and Wang have been using the SDSS Toolkit to evaluate what students learned from several graduate level courses at NJIT, including three face-to-face sections and three online sections. These exercises were trials for the researchers to examine whether the students' perceptions of the course are the same as the course objectives designed by the instructor. It can also show if a large distributed group could use this sort of software asynchronously to efficiently agree on a list of items, including multiple rewordings as a large group contributed to the quality of the resulting list, and a preference rating for the items on the list that represented the collective intelligence of the group.

8.2 Course Background

NJIT has been employing group communication software to deliver distance-learning courses and to enhance face-to-face classes since the early 1980's. Currently, most graduate level courses in the Information Systems Department are delivered through face-to-face lectures combined with online activities. Students registered in a face-to-face section are encouraged to use a computer conferencing system to further discuss the course topics, in addition to listening to the lectures in class. Most of the courses are also offered online, combining lectures on CD ROM with discussions and collaborative assignments in the same conferencing system.

Three graduate level courses in the Information Systems Department at NJIT – Management of Information Systems (CIS 679), Evaluation of Information System (CIS 675), and Design of Interactive Systems (CIS 732) – were utilized in these case studies.

As a pilot study of this exercise, in Spring 2002, students from CIS 679 used the SDSS Toolkit to come up with a rank ordered list of the most important things they had learned from the course. This course, offered by Dr. Murray Turoff, is an elective taken by graduate students in the Master's program in IS and in some other programs, including Computer Science and Management. It is also required for the Ph.D. students in IS. About half the course focuses on the task of managing software development projects for applications in an organization (Turoff et al, 2000). There was one section of face-to-face students and one section of a distance version both utilizing a conference system (i.e., WebBoard) as a merged class.

In Fall 2002, students from two sections of CIS 675 and two sections of CIS 732 participated in the same exercise. CIS 675, offered by Dr. Starr Roxanne Hiltz and Yuanqiong Wang, was required for all graduate students in IS. The course focuses on how to use both quantitative and qualitative methods to evaluate an information system from the users' points of view. One section was delivered face-to-face combined with online activity, and another was delivered online. CIS 732, offered by Dr. Murray Turoff, was an elective for all the graduate students in IS and Computer Science. The course focused on the design of interactive systems and human computer interfaces. There was also one face-to-face section and one section of a distance version both utilizing a conference system (WebBoard) as a discussion medium.

A summary of the courses included in this case study is shown in Table 8.1 below.

Table 8.1 Courses in the Case Study

Course Section	Delivery Mode	No. of Students	Time
Management of Information Systems (CIS 679-101 and 851)	Face-to-Face + Online activities + Distance section	38 (28 participated)	Spring 2002
Design of Interactive Systems (CIS 732-101 and 851)	Face-to-Face + Online activities + Distance section	23 (16 participated)	Fall 2002
Evaluation of Information Systems (CIS 675-101)	Face-to-Face + Online activities	27 (15 participated)	Fall 2002
Evaluation of Information Systems (CIS 675-851)	Online only	27 (20 participated)	Fall 2002

8.3 Web-based SDSS Toolkit

The Web-based SDSS Toolkit included two parts: a List Gathering Tool and a Dynamic Voting Tool, as briefly described in the previous chapters. Unlike most online "voting" systems, the Web-based SDSS Toolkit allowed participants to actually collaboratively formulate the statements to be voted on in a well designed, structured way.

As Turoff et al (1996) suggested, the heart of a group decision process such as the Delphi process, brainstorming, or Nominal Group Technique (Blanning, and Reinig, 2002; Dennis, et al., 1991), is the structure that relates all the contributions made by the individuals in the group and which produces a group view or perspective. In a computer-based Delphi, the structure is one that reflects continuous operation and contributions. The List Gathering Tool tries to help a group of users to collaboratively pull their ideas together, and provides a structure to organize those ideas into a list. Using this tool, users can propose their original ideas as root items in a list. During the discussion period, other users can make comments on the root items, and they can suggest better wording for the root items posted by other group members. After better wording is suggested, all group members can vote on it to decide whether the original item should be replaced by the modification suggested. When a certain pre-determined threshold (e.g. more than 50% of group members voted "yes" to the modification) has been reached, or if the group manager decides to do the replacement (depending on the system setting), the original root item will be replaced by the modification.

When the group members feel that they have reached a point of apparent agreement on wording, or a certain timeline is met, a voting session is made available by using the Dynamic Voting Tool. Note that in the current version used for this study, consolidation of items could be suggested via suggestions to modify an item, but there was no explicit method to combine two or more items into one. In the results, it was found that there were a number of places where some of the items overlapped. This has led to the following revision: participants will also be allowed to propose the deletion of a contributed item. This too will trigger the same yes/no voting process where a majority of all the active participants voting yes can cause the item to be deleted.

As with the proposal to substitute a better wording the original author can accept the suggested change anytime before a majority vote is obtained. It is also possible for the monitor of the process to perform the same function. However, the objective is to encourage the group to operate without the need of human facilitation intervention.

8.4 Evaluation Procedure

At the end of the semester, the course evaluation exercise was distributed as an optional assignment for the students who took the course. The whole process lasted two weeks. It had two phases. First, the students used the SDSS Toolkit to collectively generate their ideas in the form of a list of what they had learned from the course. And then they used rank order voting to see to what degree they had a consensus on the importance to them of the topics or skills. Students who participated in all the phases of this exercise could earn three extra credit points. A total of 115 students from the three courses (CIS 679, CIS 675, and CIS 732) did the exercise.

Phase One: Using the List Gathering Tool to List Items

In this case study, a topic was created for students in each course, e.g. topic "CIS 679 Exercise" for CIS 679. Under the topic, one list called "Things learned" was created as the workspace for students to do the exercise. The students were asked to suggest a concise statement of what they felt was the single most important thing they learned in the course. If someone else had already entered it, then the student needed to come up with something next in importance that no one had previously entered.

If students wanted to present a rationale on why they thought their item was important they could put in a separate comment to the root item to state their justification and where it occurred in the material of the course. The students were free to comment on any root item in the list and that comment could be classified as "Pro", "Con", or just an impartial "Neutral" comment.

The students could propose what they thought was a better wording of the root item which is called a "modification". If more than half of the class voted "Yes" to the modification it automatically replaced the original.

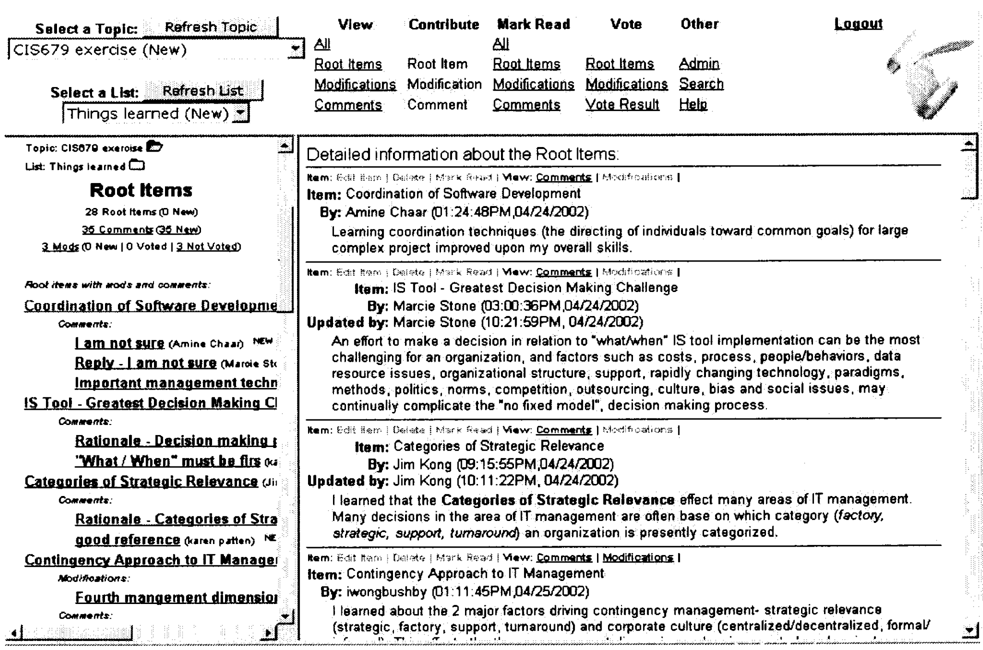


Figure 8.1 List Gathering Tool demo.

Figure 8.2 illustrates the interface and the process through which students contributed their ideas about what they had learned from the course. The left frame is the index to what may be viewed in the right frame. The controls and menus are in the frame area across the top. The system allows for the collection of multiple lists within a single exercise.

Phase Two: Using the Voting Tool to Vote on the List Items

Once the class seemed to have most of the ideas in place and all the modifications voted on, a rank order voting procedure was triggered for all the items on the list. Students input ranks for the items based on their importance. As the result, the system calculated all the votes and established a rank ordered list of items for the class as a whole.

8.5 Evaluation Results

Table 8.2 shows the summary of the results of the exercise in each course. Figure 8.2 shows the final list of items for each course in the form of the "top ten things learned." For example, as the result of the exercise, the students in CIS 679 produced 28 root items, 3 modifications (Mods), and 35 comments. In total, 24 students voted on the 28 root items using rank order voting. The items were listed in rank order as determined by an algorithm using Thurstone's law (Thurstone, 1927; Li et al, 2000) which results in a single group scale providing meaningful interval measures of differences in preference. The top ten list items ranked by the students in CIS 679, CIS675 and CIS732 were shown in Figure 8.2a, 8.2b and 8.2c separately:

Data Display: | Data Table | Bar Chart | HorizontalBar | Line | Pie Chart | Raw Data | View Comments

List Name: Things learned from CIS679 (Round 1)

Voting Method: Rank Order Voting

Voting Period: ***06/May/2002*** **to** ***25/May/2002***

Display Voting Result

Count only the last vote if a voter voted multiple times

Data Table: Thurstone's Law Result

Data Calculation: | Thurstone's Law | Borda Count | Condorcet | Mean   Distributions of Votes

Rank Order	Item (Discription)	Thurstone's Law	Dis. Above	Dis. Below	25% point	50% point	75% point	Total Votes	Vote Change
1	Runaway Projects	16.50	0	9.72	6.76	4.50	4.11	24	2
2	Categories of Strategic Relevance	6.78	9.72	0.02	6.65	4.11	2.09	24	2
3	Coordination of Software Development	6.76	0.02	0.11	6.65	4.18	2.10	24	2
4	IS Tool - Greatest Decision Making Challenge	6.65	0.11	0.51	6.14	4.11	2.10	24	2
5	Significance of 'people' issues	6.14	0.51	0.96	4.26	3.04	2.76	24	2
6	Risk management during the life of a project	5.18	0.96	0.68	5.18	3.92	2.42	24	2
7	Project management	4.50	0.68	0.24	4.26	3.48	2.27	24	2
8	Managements trade offs	4.26	0.24	0.08	5.18	2.53	2.27	24	2
9	Managing Change	4.18	0.08	0.07	6.65	3.04	2.27	24	2
10	Contingency Approach to IT Management	4.11	0.07	0.19	6.65	3.92	1.89	24	2

Figure 8.2a Voting result (partial) for CIS 679.

Data Display: | Data Table | Bar Chart | HorizontalBar | Line | Pie Chart | Raw Data | View Comments   My History

List Name: Things learned (Round 1)

Voting Method: Rank Order voting

Voting Period: 05/Dec/2002 to 11/Feb/2003

Display Voting Result

Count only the last vote if a voter voted multiple times

Data Table: Thurstone's Law Result

Data Calculation: | Thurstone's Law | Borda Count | Condorcet | Mean   Distributions of Votes

Rank Order	Item (Description)	Thurstone's Law	Dis. Above	Dis. Below	25% point	50% point	75% point	Total Votes	Vote Change
1	How to conduct Experimental research?	32.96	0	12.19	20.77	10.58	9.57	29	18
2	Practicality of Protocol Analysis	20.77	12.19	1.31	12.39	9.24	7.57	29	17
3	Statistical Methodology for evaluating significance	19.46	1.31	2.86	16.48	9.57	7.25	29	18
4	Essential ordered Steps in Conducting an Experiment	16.60	2.86	0.12	12.39	8.67	7.57	29	18
5	Protocol Analysis - Learning the cognition process	16.48	0.12	4.09	16.48	9.57	6.08	29	18
6	Survey Methodology	12.39	4.09	0	12.39	9.24	4.02	29	18
6	Methodology of Questionnaire Construction for IS surveys	12.39	0	1.72	10.67	9.24	6.97	29	18
8	Understanding Qualitative Methods	10.67	1.72	0.09	10.58	7.25	5.96	29	18
9	Experimental methods applied in IS study	10.58	0.09	0.51	16.60	8.67	4.84	29	18
10	Evaluation of Information Systems is a Formal Scientific Process	10.07	0.51	0.5	10.67	7.25	4.84	29	17

Figure 8.2b Voting result (partial) for CIS 675.

Data Display: | Data Table | Bar Chart | Horizontal Bar | Line | Pie Chart | Raw Data | View Comments   My History

List Name: Things learned (Round 1)
Voting Method: Rank Order voting
Voting Period: 06/Dec/2002 to 11/Feb/2003

Display Voting Result
Count only the last vote if a voter voted multiple times

Data Table: Thurstone's Law Result

Data Calculation: | Thurstone's Law | Borda Count | Condorcet | Mean   Distributions of Votes

Rank Order	Item (Description)	Thurstone's Law	Dis. Above	Dis. Below	25% point	50% point	75% point	Total Votes	Vote Change
1	know your users	9.30	0	0.44	9.30	6.93	5.12	13	3
2	Least effort	8.86	0.44	1.93	8.86	6.93	4.10	13	3
3	The Metaphor : Analysis and Selection	6.93	1.93	1.78	9.30	5.15	4.10	13	3
4	Interfaces, mental models and implementation models	5.15	1.78	0.03	6.93	5.12	1.75	13	3
5	Trade off	5.12	0.03	1.02	8.86	5.12	2.37	13	3
6	too much focus on consistency means not enough focus on users and their tasks	4.10	1.02	1.5	6.93	5.15	1.75	13	3
7	Using psychology to enhance interface design	2.60	1.5	0.23	5.15	2.37	1.75	13	3
8	Simplicity and usability in user interfaces	2.37	0.23	0.53	5.12	2.60	1.84	13	3
9	Design of a Web-based Interactive System	1.84	0.53	0.09	5.15	2.60	1.17	13	3
10	Usefulness	1.75	0.09	0.58	5.15	2.37	1.17	13	3

Figure 8.2c Voting result (partial) for CIS 732.

Table 8.2 Summaries of Case Study Results

Course	Number of Students Participated	Number of Root	Number of Modifications	Number of Comments	Number of Votes
CIS 679	28	28	3	35	24
CIS 675	35	42	3	60	29
CIS 732	16	15	5	46	13

With the Dynamic Voting Tool, one can visualize the relative comparison of alternative results on the same data set, which may present opposing different views of the group results. For example, rank order results can be calculated by different methods, such as Thurstone's Law, Borda Count, Cordorcet's Law, mean/average, distributions of the votes in terms of the ranks, or simply the raw data (i.e. individual votes). One can choose to display the data in a data table or graphically (e.g., bar chart, horizontal bar, line, or pie chart). In Figure 8.2, Thurstone's Law results are displayed in a data table. Therefore, one can identify not only the rank order of the group result, but the meaningful distances between list items.

The rank ordered list from each course showed the perceived class achievements of the students. The instructors used these results to check whether the items proposed by the students match the original course objective in the instructors' mind.

8.6 Feedback from Instructors

This section represents the instructors' attempt to take on the role of a "user" of the system. The lead instructor for CIS 675, Dr. Starr Roxanne Hiltz, felt that the top items represented the most important topics in the course, but only if several of the items were combined. For example, questionnaire construction and sample survey methodology were covered in two separate items tied for rank six, and also mentioned in an item ranked as number 21; if they had been combined, the combined ranking might have been higher. The qualitative methods taught, including protocol analysis or the "thinking out loud" method, were described in separate list items ranked as numbers 2, 5, 8, 24 and 26. A real "surprise" was the very low ranking of the importance of learning how to understand published research articles in information systems. This skill was listed in the course objectives in the syllabus as one of the "top five" but was listed and ranked only as number 41 out of 42 by the students. Apparently they do not value the ability to read and understand journal research articles in Information Systems as much as the instructor does. Alternatively, it may be that the students felt the prior course "Principles of

Information Systems" (CIS 677) had covered that topic to a point where they did not need added skill in this area except for the understanding of professional evaluation studies.

For CIS 679, the students contributed all the items the professor expected during phase one. However, the final rank ordered list was a surprise to the professor. For example, not only was "Runaway Project" ranked No.1, but also its Thurstone's Law results were about two times higher than the No.2 item. A runaway project is one for which the cost is at least twice as much as originally planned. Upon reading the comments made on the item, it was observed that this topic became an organization factor or metaphor around which the students associated much of the lecture material dealing with the problems of the development process. So even though only two lecture hours was spent upon this topic as an introduction to the development process, it provided a cognitive framework for the organization of an additional 15 hours of lecture. This was a total surprise to the professor. It was also noted that items seven to ten had considerable overlap and many similarities. However, the fact that the scale values are all very close to one another is an expression of this similarity of the items which is a natural result of the Thurstone's scaling process.

In CIS 732 the top ten items are more equally distributed along the range of the scale values and the items are more distinct and dissimilar in nature. This was a more likely result from a smaller class where each member was asked to contribute only one item. In the future the proposal change to allow deletions should help to minimize the occurrence to overlapping items through the combination of the deletion and replacement process to allow minimization of duplication for the group results.

The important finding from this application of the technology is that instructors may well discover insights about the course they are teaching that are not easy to otherwise determine. It also appears to be very beneficial to the students as is evident in the comments on the proposed items which get to be very interesting insights into the ways the students assess what they have learned.

8.7 Summary and Discussion

These class exercises gave the researchers an opportunity to explore the use of the SDSS Toolkit in an asynchronous distributed learning environment. It shows how one can utilize the new SDSS Toolkit to enhance learning for both face-to-face and distance learning classes. Assessing the achieved course objectives helps not only the students to review what they have learned, but also the instructors to improve their future teaching. The exercise turned out to be very successful.

However, the results also indicated the need for an explicit process to combine or consolidate initially separate items on the list. In keeping with the spirit of making each operation very straightforward and simple, it was felt that adding the deletion proposal to the rewording proposal and having them each work exactly the same way would keep the tool very easy to use. The design of this asynchronous communication process for large groups is in the spirit of an online "Roberts-rules-order." The fact that each member may address any motion or proposal at any time is the key to allowing asynchronous operation for large groups. How participants voted is not identified and comments may be entered anonymously so that the system can support a complete Delphi process (Linstone and Turoff, 1975). The Delphi method may be utilized as a learning tool for collaborative class exercises.

For this kind of exercise, with the addition of a consolidation mechanism, multiple rounds of discussion and voting will help students to arrive at a final list of items with little duplication. Due to the time constraints of the case studies reported here which occurred during the last two weeks of the course, the researchers could only conduct one round of discussion and voting.

This system can also be used by all the students in a class to continuously explore pragmatic issues in a particular course such as tradeoffs in the design of an information system or an interface. For any course with pragmatic content, this would be an interesting way to have the students collectively pool their interpretations of what they are learning and see to what degree they have a consensus on pragmatic issues in the course.

CHAPTER 9

CONCLUSIONS AND FUTURE RESEARCH

Voting theory, methods and applications in Group Decision Support Systems (GDSS) need to be further studied. The design and development of a complex web-based collaborative Dynamic Voting Tool is just the first step. The toolkit needs to be expanded to support more voting methods and to support truly dynamic group voting processes, more GSS research can be done to explore the relationship between voting and group decision-making processes in a Social Decision Support System (SDSS).

Given the variety and complexity of alternative voting methods, one should not take voting for granted. A voting tool that not only integrates multiple voting methods, but also provides insights into the possible application situations with the strength and weakness of each voting method can be a truly useful tool. The concept of Human Dynamic Voting (HDV) defined in this dissertation combines the features of Delphi process and Nominal Group Technique, and provides continues voting and feedback in a group process. It was supposed to enhance understandings among group members, and help to expose conflicts and/or inconsistencies during decision-making in a positive way.

The We-base Dynamic Voting Tool developed by the author integrated multiple voting and scaling methods, and the dynamic voting feature. It has been proved to be successful and very useful through the controlled experiment and field studies. Results from the open-ended System Survey as discussed in Chapter 5 indicated that the Dynamic Voting Tool was appreciated by most users with favorite evaluations in terms of its interface and functionality. As compared to the WebBoard, the data analysis results indicated that the Dynamic Voting Tool is at least as good as it in many ways.

The SDSS system works very well when the group is motivated and this was certainly evident in the field trials. Motivation has always been a key element in success in any group processes. The successful use of the voting tool in the field studies further indicated that this tool could be applied to many areas such as course evaluations or other very practical applications, such as creating a list of project problems or bugs and voting on which are the most serious for immediate treatment and how they have to be resolved to avoid fouling up the work of others in the group.

In this dissertation, the hypotheses were not supported in most cases based on the experimental data. There were several possible explanations for this lack of support. First, the subjects were lack of motivation to carry out the task and the overall participation was poor. Second, the task and the procedures were complex and the subjects underestimated the task, therefore, they didn't put enough effort into it. It was obvious that some of the subjects simply didn't do the work. Third, the training was relatively inadequate, and the subjects were not able to get familiar with the toolkit as they did with the WebBoard. Fourth, the subjects were not used to the idea of Human Dynamic Voting, therefore, they didn't apply it very much. Fifth, due the bad timing and limited time period, the subjects encountered several conflicts with other experiments, mid-tem exams, or course withdraw. Therefore, many subjects weren't able to focus on the experiment, or just drop out of it. Finally, the conditions were not evenly assigned due to the change of student body. Baseline condition run at Spring 2002 had seemingly different subjects body than that of Fall 2002. Therefore, it made a big difference.

Although the statistical data analysis results of the experiment failed to support most of the hypotheses, such as the perceived quality of decision-making, the perceived satisfaction (process and solution), quality of decision-making as judged by two sets of experts, and the degree of participation, the author did get some significant results concerning the comment length and the contribution of the coordinators. It indicated that the Dynamic Voting Tool did save some effort on information exchange. And group coordinators did contributed much more than group members due to the heavier responsibility.

Significant results were also found in comparing graduate students to undergraduate. This seems to indicate that students with more experience tend to accept this kind of system more quickly. In a real organizational setting, a group of experts who want to solve a very complex issue might benefit from this kind of system if they used it frequently or over a period of time longer than the experiment period.

There are many GSS research issues, especially in the context of a social decision support system, that can be explored with the help of such a Dynamic Voting Tool (combined with the List Gathering Tool). Future research should concentrate on the following directions:

(1) Improve the Dynamic Voting Tool to support true dynamic voting features while further improving the usability and functionality of it. Although the current Dynamic Voting Tool supports some dynamic voting features, that is not enough. One of the most interesting aspects of a Social Decision Support System is that the voting process must be continuous and it must be of such a nature as to help filter and organize the resulting material. And as part of a SDSS Toolkit, this is the goal that needs to be fulfilled in future voting tool development. As explicitly expressed by Murray Turoff (2000), the dynamic voting should operate like this:

As in the Delphi process, individuals should be allowed to change their vote at any time so as to maximize the opportunity for the material being supplied to influence the judgments of the other participants. Furthermore, not everyone is required to vote on every item. Given that one expects participants with many different backgrounds, not everyone may feel able to make a judgment about all the choices. They may also feel they wish to wait until they learn more about some of the options, before voting. By the very nature of this process we are interested in the relative value or importance of any number of options. As soon as an option is added to the list it should be ready for voting. The voting status should be clear to the participants with respect to the current vote and the status of the vote.

(2) Explore more issues on SDSS system's design and experimentation. This dissertation has provided a preliminary implementation of part of a SDSS system. There are more issues to explore. For example, scaling as the theory of constructing measurement instruments for human judgment is a very appropriate way to view scaling methods within the context of dynamic voting by humans. Scaling is the tool that focuses on producing the information that can lead to better visualization by the individuals and the group on what is really happening:

- To what degree is there a consensus on given items or relationships?
- To what degree is there disagreement?
- How distinctive is a given vote result relative to another vote results?
- What appears to be the current position of the group as a whole?
- What appears to be the voter's position relative to others?
- Are there subgroups of voters who have their own consistent viewpoints?

- What are the key qualitative items that appear to be influencing convergence or divergence in the voting process?
- Are there underlying items in the structure that can lead to a better synthesis of the higher order items in the structure?

The hope for the approaches taken in this paper is that the proverb that "N heads are better than one" can be true more often and that some degree of collective intelligence can be obtained. This is defined as a state in which the collective analysis of the group as a whole is better than any single member could have achieved acting alone. This is a state we would like to bring about more frequently than currently seems to happen in the real world.

There are many other issues in the design of such social decision support systems that deserve exploration and even some controlled experimentation. In this dissertation, the author did not go into details on the possible options for the participants to first arrive at a consensus on the meta variables such as the thresholds for such things as acceptance or replacement. Involving the users in the setting of the process variables can be very desirable. If the group represents an organizational membership, this is probably a very feasible and desirable pre-step to the execution of the examination of the issue. Anything that will promote involvement in the design will probably have a positive benefit on increasing motivation and resulting participation levels.

(3) Explore the relationship of Voting and GSS. Voting in GSS has been seen as a straightforward task. However, the underlying relationship among the input-process-output connection of voting is complex, and yet not fully understood (Cheng et al, 2001). Several directions can be pursued for the study of voting in GSS. One approach is to

build theories about the use of voting in GSS. For example, a theory that classifies voting methods based on their effects. These theories can adopt theories from other relevant fields such as Social Choice Theory (Arrow, 1951; Craven, 1992), Prospect Theory (Tversky and Kahneman, 1992), and Choice Shift (El-Shinnawy and Vinze, 1998; Friedkin, 1999). Researchers can also construct a contingency theory that matches the use of voting to different factors such as group size, task type, and process structure.

Another approach is the empirical approach. One possible direction is to build different voting tools into GSS to test the relationships among the input-process-output factors. Findings by this approach can be used to verify theories and to refine future GSS design. Researchers can also observe the changes in user behavior to study the long-term effects of voting tools in GSS.

Undoubtedly, this will be a rich area for future GSS research.

APPENDIX A

EXPERIMENTAL TASK

The following document is the "Computer Purchasing Task" used for the experiment.

Computer Equipment Purchasing Task

Background

You are an employee of a small state university. The university is about to make a new purchase of approximately 800 personal computers for the next academic year and establish the vendor who will be supplying personal computers (desktop models) for at least a three year period at a minimum rate of 600 machines per year. This will be a major upgrade of personal computers for many faculty and staff members and new machines for about 500 entering freshmen. A RFP (Requests for Proposal) is required. In past RFPs, the university has had proposals from such companies as IBM, Dell, Gateway, Compaq, Hewlett-Packard, Micron, DTK, Acer, NEC, and Toshiba. It has also had proposals in the past from companies that no longer exist. As a state university it must be very clear in the RFP as to the criteria by which a winning bid will be awarded and the winning bid as well as the RFP becomes a public document. A loser in this contest, after examining the winning bid, could actually sue if they felt the award went to a company that did not respond as well as they did to the RFP.

It is known that the university can afford for the budget for this purpose machines costing up to $1500 per machine. But individuals can add more dollars from other sources to increase the power of the machine they get from the vendor. The university has a normal mix of academic disciplines and a range of faculty and staff from novice and casual users to power users.

Task

You have been invited by the CIO (Chief Information Officer) and the President of the University to be a member of the Task Force charged with defining the specific requirements or criteria that will be used in the RFP to choose among the vendors and their machines. The objectives of your Task Force are:

- To establish the set of absolute and relative criteria to choose the vendor and the machines,
- To arrive at a relative importance (rank order) of all relative criteria,
- To provide the supporting reasons for the criteria and their relative importance.

Absolute criteria are items like:

- The machine must have a minimum of 128MB of core memory,
- The base machine must not cost more than $1,500,
- The machine must contain a CD-RW drive.

Relative criteria are items like:

- Exceeding the minimum core memory requirement in the proposed base machine,
- The reputation for reliability of the proposed manufacture (which may be different from the bidder),
- The service reputation of the bidder.

The only absolute criterion that has already been determined is that the base machine will not exceed $1,500. Any others are your choice. Be careful that your absolute requirements do not result in it being impossible to configure a base machine for $1,500 or less. Individual students, faculty and staff may add funds from other sources and budgets to request a more powerful machine from the vendor so that the bidder needs to supply the costs of additions to the base machine.

You have two weeks to work on this task. At the end of the second week, your Task Force needs to submit a group report. The report will be reviewed by the Committee on Academic Affairs (Deans and Chairs), the CIO, the President and the Provost, and then turned over to the Purchasing and Legal departments for the final composition of the RFP.

The contents of this report must include:

1) a description of each of the absolute criteria.
2) reasons for choosing each absolute criterion.
3) a description of each of the relative criteria.
4) reasons for choosing each relative criterion.
5) the relative importance of each of the relative criteria as a rank-ordered list.
6) reasons that support the final order of importance for the relative criteria.

It is an honor being selected to work on this fundamental analysis required for the final RFP. With this project, you will be able to help your university to make the important choice of a vendor to deliver improved services and Personal Computer options to the university community.

APPENDIX B

SUBJECT CONSENT FORM

The following document is the "Consent Form" used for the experiment.

Consent Form

Name of Project Director or Principal Investigators: **Zheng Li and Yuanqiong Wang**

Title of Project: **Social Decision Support Systems in Distributed Group Support Systems**

I acknowledge that on 06/17/2003, I was informed by **Zheng Li and Yuanqiong Wang** (Investigators) of NJIT (under the supervision of Dr. Roxanne Hiltz) of a project concerning or having to do with the following:

Computer Supported Social Decision Making in Distributed Group Support Systems

I was told with respect to my participation in said project that:

1. The following procedures are involved:
   - Carrying out one or more decision tasks
   - Filling out several questionnaires
   - All communications during the decision-making task will be recorded, and later analyzed.

2. The following possible risks are involved:
   No known risk; confidentiality of the data will be fully protected.

3. The following possible alternative procedures that may be advantageous to me include:
   An alternative assignment relevant to the topic of the experiment will be given.

4. The following benefits are expected by my participation:
   - An opportunity to learn about experimental design and procedures,
   - An opportunity to learn decision making techniques,
   - An opportunity to contribute to the design of better computer systems to support social decision-making.

I am fully aware of the nature and extent of my participation in said project and possible risk involved or arising there-from. I hereby agree, with full knowledge and awareness of all of the foregoing, to participate in said project. I further acknowledge that I have received a complete copy of this consent statement. I also understand that I may withdraw my participation in said project at any time without any negative consequences.

Name: ____________________	Semester: _________________
Email: ____________________	Professor:_________________
Phone: ____________________	Course #:_________________

APPENDIX C

BACKGROUND QUESTIONNAIRE

The following document is the "Background Questionnaire" used for the experiment.

Background Questionnaire

The purpose of this questionnaire is to gather some background information. All information is confidential.

Part I. Please check the answer(s) which applies to you:

1. I am an: _____ Undergraduate junior _____ MBA student
_____ Undergraduate senior _____ MSIS student
_____ Ph.D. student _____ MSCS student
_____ Other; please specify ___________________

2. My undergraduate major is/was:
_____ Accounting _____ Management
_____ Finance _____ Marketing
_____ Information Systems _____ Engineering
_____ Other; please specify: ________________

3. My nationality is: ________________

4. My ethnic background is:
_____ Black/Afro American
_____ Hispanic (Mexican, Puerto-Rican, etc.)
_____ White
_____ Asian or Asian American
_____ Other

5. I am a: _____ female _____ male

6. My age is: _____ under 23 _____ 31-40
_____ 23-30 _____ over 40

7. English is my native or first language. _____ Yes _____ No
If you were **not born in the US**, the number of years you have lived in the US _______

8. The total number of months I have been employed full-time (Do count summer or other vacation jobs if worked full-time) ____________ months

9. I have used WebBoard _____ Never _____ Three to ten times
_____ Once or twice _____ Frequently

10. I have bought computer(s) or workstation(s) before. _____ Yes _____ No
If **Yes**, please answer the next two questions, otherwise skip them.
10.1. I bought it for _____ myself _____ organization _____ other
10.2. I have bought computer(s) ___ once ___ twice ___ more than two times

Part II. Directions: After each statement, circle the answer that applies to you. There are no right or wrong answers. Work quickly; just record your first impression.

1. My confidence in taking the responsibility to recommend a choice for a personal computer for an organization would be:

very high high medium low very low
1--------------2-----------------3-------------4-----------------5

2. My confidence in contributing information and insight to a group taking the responsibility to recommend would be:

very high high medium low very low
1--------------2-----------------3-------------4-----------------5

3. When it comes to computers, I consider myself a:

novice 1------------2-----------3---------4----------5 expert

4. My level of experience in working in groups is:

very high high medium low very low
1--------------2-----------------3-------------4-----------------5

5. My level of experience in making actual business decisions is

very high high medium low very low
1--------------2-----------------3-------------4-----------------5

6. I dislike participation in group discussions.

Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree
1--------------2-----------------3-----------------------4-----------------5

7. Engaging in group discussions with new people makes me tense and nervous.

Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree
1--------------2-----------------3-----------------------4-----------------5

8. I have easy access to WebBoard from home or work.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1	2	3	4	5

9. Generally, I am comfortable participating in group discussions.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1	2	3	4	5

APPENDIX D

TASK SURVEY

The following document is the “Task Survey” used for the experiment.

Task Survey

Part I. Please rate the task on each of the following dimensions by writing down the number which most closely matches your opinion.

1. How much effort was required to complete this task?

very little effort	some effort	average effort	A lot of effort	extraordinary effort
1	2	3	4	5

1--------------------2--------------------3------------------4---------------------5

2. To what degree do you think the task was interesting and motivating to you?

extremely boring — neutral — extremely interesting

1--------------------2--------------------3------------------4---------------------5

3. How important was it for you to complete this task?

not important — moderately important — critical

1--------------------2--------------------3------------------4---------------------5

4. How easy or difficult did you find this task as an individual?

extremely easy — neutral — extremely difficult

1--------------------2--------------------3------------------4---------------------5

5. How enjoyable did you find to work on this task using the procedures and system provided?

extremely unpleasant — neutral — extremely enjoyable

1--------------------2--------------------3------------------4---------------------5

6. Did the task description provide you with enough information to easily carry out the task?

definitely — somewhat — not at all

1--------------------2--------------------3------------------4---------------------5

7. Did the task description make it clear what was to be accomplished?

unclear — fairly clear — very clear

1--------------------2--------------------3------------------4---------------------5

8. Was there a clearly defined body of knowledge that could guide you in doing this work?

definitely — somewhat — not at all

1--------------------2--------------------3------------------4---------------------5

9. Was there an understandable approach that could be followed in doing your contributions to the task?

definitely		somewhat		not at all
1	2	3	4	5

10. To what extent did you feel you had the background (education and/or experience) needed to carry out this task?

not at all	little extent	some extent	great extent	very great extent
1	2	3	4	5

Part II. Please give short comments on the following questions:

1. Below please identify any aspect of the task or the task materials that you found to be confusing or difficult to understand (for example, instructions, vocabulary, etc).

2. Below please write down your own ideas about what are the most important absolute criteria and what are the most important relative criteria that come to your mind.
IMPORTANT NOTE: Please do NOT refer to your group report/discussion. DO THIS FROM YOUR OWN MIND!

APPENDIX E

SYSTEM SURVEY

The following document is the “System Survey” used for the experiment.

System Survey

Part I. Please rate the system you used for the experiment on each of the following dimensions by selecting the number most closely matches your opinion.

Q1. The system was easy to learn.

Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree
1--------------2----------------3----------------------4-----------------5

Q2. The training materials of the system were easy to follow.

Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree
1--------------2----------------3----------------------4-----------------5

Q3. I would like to recommend this system to my friends.

Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree
1--------------2----------------3----------------------4-----------------5

Q4. I don't know where to start when I log in to the system.

Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree
1--------------2----------------3----------------------4-----------------5

Q5. The interface of the system was confusing.

Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree
1--------------2----------------3----------------------4-----------------5

Q6. The training on the system was helpful for me to carry out the experimental task.

Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree
1--------------2----------------3----------------------4-----------------5

Q9. I used the system without needing much help.

Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree
1--------------2----------------3----------------------4-----------------5

Q10. I needed to use help a lot on the system.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

1---------------2------------------3------------------------4------------------5

Mark your answers on the scale, expressing your opinions on your impressions of the system.

Q8. Easy to understand	1 2 3 4 5 6 7	Hard to understand
Q11. Easy to use	1 2 3 4 5 6 7	Hard to use
Q12. Clear	1 2 3 4 5 6 7	Confusing
Q13. Intuitive	1 2 3 4 5 6 7	Unintuitive
Q14. Fast	1 2 3 4 5 6 7	Slow
Q15. Sufficient Feedback	1 2 3 4 5 6 7	Little Feedback
Q16. Friendly	1 2 3 4 5 6 7	Unfriendly

Q17. While using the system I felt challenged to do my best work.

Strongly agree 1----2----3----4----5----6----7 Strongly disagree

Q18. I felt frustrated by using the system.

Strongly agree 1----2----3----4----5----6----7 Strongly disagree

Q19. Using the system was fun.

Strongly agree 1----2----3----4----5----6----7 Strongly disagree

Q20. I really feel my work on the system accomplished something.

Strongly agree 1----2----3----4----5----6----7 Strongly disagree

Q21. While using the system, I felt comfortable.

Strongly agree 1----2----3----4----5----6----7 Strongly disagree

Q22. I enjoyed using the system.

Strongly agree 1----2----3----4----5----6----7 Strongly disagree

Q23. I don't like the system.

Strongly agree 1----2----3----4----5----6----7 Strongly disagree

Thinking back over your experience so far with the system, how frequently have you felt

	Almost Always	Most of the time	Some times	Almost never	Never
Q25. Distracted by the mechanics of the System	○	○	○	○	○
Q26. Constrained by the System Design	○	○	○	○	○
Q27. Overloaded with information	○	○	○	○	○
Q28. Able to understand	○	○	○	○	○

Part II. Other measurements:

Q2.1. Which features do you think are the most useful?

Q2.2. Which feature do you think is the least useful?

Q2.3. What features should be added to this system?

Q2.4. What features should be removed from the system?

Q2.5. What changes would you recommend to make the system easier to use?

Q2.6. What changes would you recommend to make the system more effective for the task you were given?

APPENDIX F

POST-QUESTIONNAIRE

The following document is the "Post-Questionnaire" used for the experiment.

Post-Questionnaire

Part I. Please circle one number based only on your experience with your group.

1. The overall quality of the group's work was:

   Poor 1----2----3----4----5 Good

2. The issues explored during the group's work were:

   Trivial 1----2----3----4----5 Substantial

3. The content of the group's work was:

   Carefully developed 1----2----3----4----5 Carelessly developed

4. The manner in which the participants examined issues was:

   Non-constructive 1----2----3----4----5 Constructive

How would you describe your group's problem-solving process?

5. Efficient	1	2	3	4	5	Inefficient
6. Coordinated	1	2	3	4	5	Uncoordinated
7. Fair	1	2	3	4	5	Unfair
8. Understandable	1	2	3	4	5	Confusing
9. Satisfying	1	2	3	4	5	Unsatisfying

10. How satisfied or dissatisfied were you with the quality of your group's solution?

    Very dissatisfied 1----2----3----4----5 Very satisfied

11. To what extent does the group's work reflect your inputs?

    Not at all 1----2----3----4----5 Very great extent

12. To what extent do you feel committed to the group's solutions?

    Not at all 1----2----3----4----5 Very great extent

13. Issues raised in the group were discussed thoroughly.

    Strongly agree 1----2----3----4----5 Strongly disagree

14. To what extent are you confident that the group's solutions are correct?

Not at all 1----2----3----4----5 Very great extent

15. I am in complete agreement with the group's work.

Strongly agree 1----2----3----4----5 Strongly disagree

16. The group discussions enabled me to better understand the positions of other members of my group.

Strongly agree 1----2----3----4----5 Strongly disagree

17. The group decision process uncovered valid alternatives that I had not considered.

Strongly agree 1----2----3----4----5 Strongly disagree

18. The group decision process made me critically reevaluate the validity of the alternatives that I had thought of.

Strongly agree 1----2----3----4----5 Strongly disagree

19. I experienced pressure, either to conform to a particular viewpoint or not to contradict others.

Very much 1----2----3----4----5 Not at all

20. I tried to go along with the group consensus even if I disagreed somewhat.

Strongly agree 1----2----3----4----5 Strongly disagree

21. To what extent did the group experience conflict?

Not at all 1--------2-------3--------4----------5 Very much

22. Did the group handle conflict effectively?

Not at all 1--------2-------3--------4----------5 Very much

23. Did the group members acknowledge and confront conflict openly?

Not at all 1--------2-------3--------4----------5 Very much

24. Our group's approach helped us to resolve conflicts that arose in the course of our work.

Strongly agree 1-------2-------3-------4-------5 Strongly disagree

25. The system used in the experiment resulted in information overload.

Strongly agree 1-------2-------3-------4-------5 Strongly disagree

26. The system used in the experiment increased the amount of the irrelevant information making it harder to focus on what needed to be done.

Strongly agree 1-------2-------3-------4-------5 Strongly disagree

27. The system used in the experiment caused me to miss important information.

Strongly agree 1-------2-------3-------4-------5 Strongly disagree

Part II. Other measurements:

1. Participation in the group's work was:

Unevenly distributed1----2----3----4----5 Evenly distributed

2. The group members dealt with the issues:

Systematically 1----2----3----4----5 Non-systematically

3. The interpersonal relationships among the group members appeared to be:

Unhealthy 1----2----3----4----5 Healthy

4. The group was:

Not goal directed 1-----2----3----4----5 Goal directed

5. The group members initiated discussions on:

Relevant issues 1-----2----3----4----5 Irrelevant issues

6. The group members' contributions were:

Poorly amplified 1-----2----3----4----5 Well amplified

7. Participation in the discussions was:

Unevenly distributed 1-----2----3----4----5 Evenly distributed

8. Ideas expressed in the discussions were:

Critically examined 1-----2----3----4----5 Uncritically examined

9. I felt frustrated and tense about others' behavior.

Strongly agree 1----2----3----4----5 Strongly disagree

10. I rejected others' opinions or suggestions.

Strongly agree 1----2----3----4----5 Strongly disagree

11. My opinions or suggestions were rejected.

Strongly agree 1----2----3----4----5 Strongly disagree

12. All of the group members showed attention and interest in the group's activities.

Strongly agree 1----2----3----4----5 Strongly disagree

13. I felt reluctant to put forward my own ideas.

Very much 1----2----3----4----5 Not at all

14. There was a high degree of participation on the part of members.

Strongly agree 1----2----3----4----5 Strongly disagree

15. The work of the group was left to those who were considered most capable for the job.

Very much 1----2----3----4----5 Not at all

16. There were long periods during which the group did nothing.

Very much 1----2----3----4----5 Not at all

17. The work of the group was well divided among members.

Strongly agree 1----2----3----4----5 Strongly disagree

18. Every member of the group did not have a job to do.

Strongly agree 1----2----3----4----5 Strongly disagree

19. The language of the group prevented participation.

    Strongly agree 1----2----3----4----5 Strongly disagree

20. One or two members strongly influence the group decisions.

    Strongly agree 1----2----3----4----5 Strongly disagree

21. I feel one person influenced the group's work more than the rest of the group.

    Strongly agree 1----2----3----4----5 Strongly disagree

22. Someone (other than the assigned group coordinator) emerged as an informal leader.

    Strongly agree 1----2----3----4----5 Strongly disagree

23. The group coordinator performed his/her functions well.

    Strongly agree 1----2----3----4----5 Strongly disagree

24. To what extent were the people in your group friendly?

    Very friendly 1----2----3----4----5 Not friendly at all

25. To what extent were the people in your group helpful?

    Very helpful 1----2----3----4----5 Not helpful at all

26. To what extent did the people in your group take a personal interest in you?

    Very interested 1----2----3----4----5 Not interested at all

27. To what extent did you trust the members in your group?

    Great deal of trust 1----2----3----4----5 No trust at all

28. To what extent did you look forward to working with the members of your group?

    Very much 1----2----3----4----5 Not at all

29. All the members of the group contributed to the final result.

    Strongly agree 1----2----3----4----5 Strongly disagree

APPENDIX G

NJIT HUMAN SUBJECT RESEARCH REVIEW FORM

The following document was submitted to the NJIT IRB for Human Subjects Research, and was approved.

PLEASE PRINT OR TYPE

Date: July 26, 2001 Project Number: ______________________

HUMAN SUBJECT RESEARCH REVIEW FORM (A)
NJIT INSTITUTIONAL REVIEW BOARD

Name: **Starr Roxanne Hiltz**

NJIT Address: **Collaborative Hypermedia Laboratory, RM4323 GITC,**

New Jersey Institute of Technology, University Heights, Newark, NJ07102

Department: **Information Systems**

NJIT Affiliation (Check all that apply)

Faculty	X	Research Associate	
U/G Student		Doctoral Candidate	
Graduate Student		Post Doctoral	
Other			

Project Title: **Social Decision Support Systems in Distributed Group Support Systems**

This project will be conducted:

On Campus		Off Campus	
Both	X		

Anticipated Sponsor (s) of this project:

NJIT	X (matching)	Government	NSF ($180,000)
Foundation		Federal	
Organization		State	

Starting Date of Project: July 1, 1998

Closing Date of Project: June 30, 2002

To Principal Investigator: In addition to the questions below, please furnish copies of any questionnaires interview formats, testing instruments or other documents necessary to carry out the research.

The completed forms should be sent to: Robin-Ann Klotsky, Ph.D
Executive Director of Research and Development
Office of Sponsored Programs
New Jersey Institute of Technology
University Heights
Newark, NJ 07102-1982

1. Project Title: Social Decision Support Systems in Distributed Group Support Systems

2. List the name and the Faculty/Student/Staff status of the persons conducting the research:

a. Principal Investigator: Starr Roxanne Hiltz, IS (faculty)

Others:
Co-PIs:
Murray Turoff, IS (faculty)
Jerry Fjermestad, Associate Prof. SIM (faculty)

Collaborators/investigators from other organizations:
Ronald Rice (Rutgers), Rosalie Ocker (Penn State), Raquel Benbunan (Seaton Hall), Kenneth Johnson (St. Thomas U).

3. In a few words (100 or less) describe the objectives, methods and procedures of the research projects. This summary will used to describe your project to the committee on Human Subjects.

This is a continuation of a program of experiments on computer support for group decision making which has been ongoing at NJIT since the late 1970's.

The primary goal of this project is to test the effects of a newly developed anytime/anyplace group support system. This will extend our previous NSF- funded work on distributed asynchronous text-based group support systems by adding the use of Web-based decision-support tools to text based communication. We will experiment with "no tools" or "tools" modes used by the small groups over a period of time. We will also focus on several areas of research which have received little attention from other researchers but which appear promising: the interaction of task and technology, the use of more sophisticated multi-criteria decision analysis tools, and the interaction of personal characteristics with technology.

The proposed program of research will continue our emphasis on integrating theory development, empirical research, and technology innovations. The selection, development, and tailoring of state of the art Web-based technology that can be used by groups working together, will be accomplished as part of our work with the funded New Jersey Center for Multi-Media Research (NJCMR). The empirical studies will include controlled experiments using students as subjects.

It is anticipated that there will be minor changes in the questionnaires currently being used and approved for the previous phase of the project, to fit specific tasks or foci of a specific experiment. (Last reviewed and approved about 1995). Current questionnaires are attached.

4. List name and institutional affiliation of any research assistants, workers student that will be working on this project.

Students who work as research assistants in the Collaborative Hypermedia Laboratory will be involved in all phases of this project. They will help to train and orient students and assist with conducting training experimental sessions; encode and enter the data; assist with data analysis and formatting results for oral and written presentations.

In addition, Ph.D. students who are assigned as faculty assistants or who are doing a dissertation related to the subject of the project may be involved in assisting in the Collaborative Hypermedia Laboratory, which serves as a headquarters for the project. It is anticipated that these students will include Zheng Li, Yuanqiong Wang, and others.

These student assistants change slightly every semester as some graduate or go on to other jobs. In their first semester, they spend a lot of time being oriented and trained.

5. If research assistants, workers, students will be working on the project describe their qualifications, special training and how they will be supervised.

The student assistants are all "good" students (at least a 3.0 average) who have shown facility and interest in using online communication and have skills with both hardware and software sufficient to keep the equipment in the lab working and to help students and faculty members.

They are oriented on their duties in maintaining confidentiality of data. One of the students with considerable experience serves as lab manager to coordinate hours and do daily checks that everything is running smoothly. The immediate supervisor and 'trainer" of the laboratory assistants will be the principle investigator. The project director keeps in touch via daily online reports and interactions about happenings in the Lab and sets overall policies and priorities.

6. What is the age of the subjects and how will they be recruited?

College age students, both undergraduates and graduates. The experimental tasks are chosen to fit in with the subject matter of a course and to constitute a valuable learning experience in a course. For example, in a systems analysis course, the task might be to design software, and in a management course, it might be to simulate managerial decision-making. They receive questionnaires with protection of human subjects information describing the project, at pre-experiment orientation (training) or after the experiment.

7. Attendant risks: Indicate any physical, psychological, social or privacy risk or pain, which may be incurred by human subjects, or any drugs medical procedures that will be used. (This includes any request for the subjects to reveal any embarrassing, sensitive, or confidential information about themselves or others.) Also, indicate if any deception will be used, and if so, describe it in detail. Include your plans for debriefing.

There are no physical or other risks associated with the research (doing a task in a online group; answering questionnaires or being observed).

No deception will be used.

8. Evaluate the risks presented in 7.
    a. Is it more than would normally be encountered in daily life?
       No

    b. Do your procedures follow established and accepted methods in your field?
       Yes

9. How will the risk be kept at a minimum? (e.g. describe how the procedures reflect respect for privacy, feeling, and dignity of subject and avoid unwarranted invasion of privacy or disregard anonymity in any way.) Also, if subjects will be asked to reveal any embarrassing, sensitive, or confidential information, how will confidentiality of the data be insured? Also include your plans for debriefing. If subjects will be placed under any physical risk, describe the appropriate medical support procedures.

Subjects are given an "alternate assignment" if they are unwilling or unable to participate in the experiment. This would consist of a similar task done on their own. Subjects are told what data will be collected in the consent form.

As a first step in coding and entering data, the identifying information on the first page of questionnaires or report forms is removed and destroyed. An algorithm is used to transform the student ID to another number in a consistent way, so that all other transformations of other pieces of data will receive the same new "identifying number" and the pieces of data can be assembled into a research record, but the data have no personally identifying information.

Student assistants are repeatedly drilled on the importance of maintaining confidentiality. Questionnaires are kept locked up in file cabinets when not in use. No names or individually identifying information are used in any reports of results; all quotations reported are anonymous in reports.

10. Describe the benefits to be derived from this research, both by the subject and by the scientific community (this is especially important if research involves children).

Scientific community: increased knowledge about variables related to effective software and procedures for using computers to enhance the quality of group work.

Students: opportunity to learn about how experiments are conducted, with extensive debriefing, as well as to carry out an assignment as part of a group rather than individually, thus learning about teamwork.

11. Describe the means through which human subjects will be informed of their right to participate, not to participate, or withdraw at any time. Indicate whether subjects will be adequately informed about the procedures of the experiment so that they can make an informed decision on whether or not to participate.

Consent form and presentation while recruiting volunteers in classes.

12. Complete the attached copy of the Consent Form and the Institutional Review Board will make a determination if your subjects will be at risk. This Consent Form must include the following five pieces of information: (1) The purpose of the research, (2) the procedures involved in the work, (3) the potential risk of participating, (4) the benefits of the research, (5) that the subjects are free to withdraw from the research at any time with no adverse consequences.

13. Furnish copies of questionnaires, interview formats, testing instruments or other documents to carry out the research. If questionnaires are not complete please submit an outline of the questions to be used. You will have to submit the completed questionnaire to the Committee before the research can begin.

14. If the subjects will be minor children, complete Consent Form as prescribed in paragraph 12 for signature by parent or guardian. If the project is approved (regardless of the Board's determination concerning risk), it will be necessary that a Consent Form be secured for every minor child.

15. Attach copy of permission of facility to conduct the proposed research (if other that NJIT).

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