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A Group Support Systems Approach to Cognitive Mapping

Steven D. Sheetz
University of Colorado
Graduate School of Business Administration
Campus Box 419
Boulder, Colorado 80309-0419
SHEETZ_S@CUBLDR.COLORADO.EDU
(303) 492-4405

David P. Tegarden
Information and Decision Sciences
School of Business and Public Administration
California State University
San Bernadino, California 92407-2397
TEGARDEN@GALLIUM.CSUSB.EDU
(909) 880-5792

Kenneth A. Kozar
University of Colorado
Graduate School of Business Administration
Campus Box 419
Boulder, Colorado 80309-0419
KOZAR_K@CUBLDR.COLORADO.EDU
(303) 492-8347

Ilze Zigurs
University of Colorado
Graduate School of Business Administration
Campus Box 419
Boulder, Colorado 80309-0419
ZIGURS_I@CUBLDR.COLORADO.EDU
(303) 492-3490

Send correspondence regarding this paper to Steven D. Sheetz at the above address.
ABSTRACT

Cognitive maps are valuable tools for understanding individual and group perceptions. But developing such maps is a resource intensive activity. To reduce required resources, group support system (GSS) technology is proposed as an aid in uncovering cognitive maps. A GSS session was used to develop a cognitive map of users' of object-oriented (OO) techniques perceptions of OO system complexity. Seven participants identified concepts and categories, categorized the concepts, rated category importance, and defined relationships between categories. The data collected and analyses performed provide the basis for a cognitive map of the participants' perceptions of OO system complexity. A comparison with similar individual cognitive mapping results supports further investigation of using the GSS approach for identifying perceptions of complexity.

KEY WORDS AND PHRASES: group support systems, cognitive mapping, object-oriented systems, complexity

INTRODUCTION

Cognitive mapping is a set of techniques for studying and recording people's perceptions about their environment. These perceptions are recorded graphically in the form of a "mental map" that shows concepts and relationships between concepts. Computer support has been used for cognitive mapping for several years [19, 21]. For example, the COPE software generates graphics that represent maps based on keyed inputs and automated structural analysis of the maps. One of COPE's weaknesses, however, is that the researcher is an active participant who questions group members and adds concepts to the map, with the goal of guiding participants to the "right" strategy. A less interactive process may be preferred to ensure that the opinions of the researcher have a minimal impact on the perceptions of the participants. This type of "researcher-neutral" technique is desired when investigating what participants believe to be important without the potential bias introduced by the researcher's participation [2]. Ways to reduce researcher bias used in individual studies include interview scripts and detailed instructions. In group studies these controls can be implemented using group support systems (GSS) technology. Since, computer-based methods such as COPE have been used previously for cognitive mapping studies and since group support systems have potential for controlling researcher bias, it seemed logical to investigate the value of this new method. Our research question is:

Is it possible to identify perceptions of complexity by deriving cognitive maps using a group support systems approach?

In other words, will a set of procedures that is consistent with individual cognitive mapping techniques, implemented as a series of GSS activities conducted using GSS tools, be useful for discovering what is
hard to understand about a particular object or process? We explore this question by presenting how we developed the GSS approach from the individual studies we conducted and by comparing the results of a GSS-supported cognitive mapping study to results obtained in similar individual mapping studies. Although the results of these studies helps validate the appropriateness of the procedure, the focus of this paper is on the methodology used to identify perceptions, rather than a detailed interpretation of the data obtained. The methodology is of interest because it builds on previous research on cognitive mapping and GSS to provide a new approach for identifying group perceptions.

The work reported in this paper represents an evolution in methods for cognitive mapping. We began by conducting individual cognitive mapping studies to test the feasibility of cognitive maps for representing difficulties in understanding object-oriented (OO) techniques. These studies resulted in data on individuals' perceptions, including concepts, categories, and cognitive maps describing OO system complexity. However, this individual approach required very large commitments of time and effort by researchers and participants. Furthermore, to get a more general view of complexity, individual maps would have to be integrated into a combined map - a further step for which there is no accepted methodology [35]. Some techniques attempt to identify group perceptions, e.g., Delphi panels [13], but these require even greater time commitments, including additional meetings for participants (approximately half an hour per meeting) and greater coding requirements for researchers (approximately two hours per subject per Delphi round). What is needed is a more efficient process for deriving group cognitive maps. Recent advances in group support systems technology hold promise for supporting such a process.

The paper begins with an explanation about cognitive mapping and GSS, and a description of the research setting. The evolution of the procedures from the individual cognitive mapping techniques to the GSS approach is then discussed. The following section presents the results of an application of the GSS approach and compares them to results obtained in individual mapping studies. A summary of the results highlights the usefulness of the GSS approach for the study of perceptions of complexity. The paper ends with limitations, conclusions, and opportunities for further research.
BACKGROUND ON COGNITIVE MAPPING AND GROUP SUPPORT SYSTEMS

Cognitive mapping is a set of techniques for studying and recording people's perceptions of the world around them. A cause map, a special type of cognitive map, is built by connecting concepts to each other by arrows; the arrows represent assertions that one concept affects another concept. Figure 1 presents an example of a simple cause map. Many cognitive mapping techniques [2, 5, 22, 26, 30] consist of three major steps: (1) eliciting concepts, (2) refining concepts, and (3) identifying assertions that concepts are connected by causal relationships. Additional steps are necessary for the derivation of group maps. For example, Delphi panel techniques include steps to reconcile or combine individuals' idiosyncratic representations [35]. By looking at the views of others and reconsidering their own views, members of a Delphi panel can move toward consensus [13]. The authors believed this process could be more efficiently conducted using a group support system (GSS).

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Insert Figure 1.

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Group support systems (GSS) have become a well-established area of research in information systems [31]. The terminology for this type of technology varies and includes such names as groupware [32], group decision support systems [17], electronic meeting systems [15], and collaborative work support systems [4]. For purposes of this study, we define GSS as a computer-based system that combines hardware, software, and procedures to structure and support group activities in a same time/same place meeting environment. Different implementations of the GSS concept provide structure and support in different ways. For example, an automated agenda provides structure since participants know that specific activities will be conducted in a specified order during a GSS session, e.g., elicit concepts, refine concepts, and identify relationships between concepts. Each activity could be supported using a tool provided by the GSS, e.g., electronic brainstorming to elicit comments, a categorizing tool for classifying the comments, and a scoring tool for identifying relationships between categories.

Early GSS studies were conducted primarily as laboratory experiments [36, 27, 54], but data from field studies are now beginning to accumulate [18, 49]. The focus of early research was on comparing GSS-supported groups with non-supported groups in an attempt to ascertain the relative pay-off from group support technology (see [40], for a review of this work). Subsequent studies examined the impact of various aspects of the technology on the group, such as levels of support [44],
anonymity [46, 47], conflict management [41], and adoption [9]. Just beginning to emerge are
descriptive or case studies that use GSS technology to accomplish goals other than decision support,
e.g., as a research support tool [1, 14, 29]. Implementing cognitive mapping procedures is a unique
usage of GSS technology.

BACKGROUND ON OBJECT-ORIENTED SYSTEMS AND THEIR COMPLEXITY

Complex, as defined by Webster [37] is an adjective that means "involved, perplexing, difficult,
complicated, intricate." Investigating the complexity of an object or process involves learning what is
hard for users of the object or process to understand about it. For example, investigating the complexity
of the software development process involves learning what software developers believe is hard to
understand about developing software. Since complexity is based on what people believe, rather than
on reality, complexity is inherently based on the perceptions of the individuals involved.

A better understanding of the perceived complexity of information systems development
approaches could aid the information systems field. Information systems departments are considering
OO techniques as a potential solution to the perennial challenge of delivering timely and cost-effective
systems that meet users' needs [33, 42]. The popular press is promoting object orientation as a solution
to what currently ails software development [48]. However, implementing OO techniques is a difficult
process. As Fichman and Kemerer [24, pg. 19] state:

"For object orientation, the rival entrenched technology is not just a
language generation or a database model, but the entire procedural
paradigm for software development. It is therefore difficult to imagine
a more compelling instance of prior technology drag in software
engineering."

DESCRIPTION OF THE STUDY ENVIRONMENT

Our objective was to study whether it is possible to identify perceptions about OO system
complexity by deriving cognitive maps using a GSS approach. The study site was a major western
university that had GSS technology and a course in OO techniques. Thus, the setting included both the
needed technology and knowledgeable participants.

Two individual studies were conducted using variations of the Self-Q technique for cognitive
mapping [5, 6, 7]. Only two studies were conducted because of the time required to complete individual
maps. The Self-Q technique was selected because it focuses on minimizing the influence of the
researcher on the data provided by the participants. The technique consists of a series of paper-and-pencil-based activities designed to uncover an individual's ideas and beliefs. The investigator uses the resulting data to derive a cognitive map. The first participant in the study was a faculty member (not an author of this paper) who had ten years of structured analysis and design experience with a major U.S. computer manufacturer, as well as two years experience using OO techniques. This person had developed a large OO system. The second participant had three years of experience teaching OO techniques, had published an article summarizing OO analysis and design techniques, and had written several OO systems.

The results of these studies provided a basis for suggesting that the Self-Q Technique was useful for investigating the complexity of OO systems. However, this suggestion was accompanied by concerns that the development of group maps would be time consuming and require considerable interpretation by the researchers. These concerns led to a search for a process that would lead to group maps in a more efficient manner and reduce the interpretation required. This search led us to consider the use of GSS to support the development of group cognitive maps.

The GSS-supported study consisted of seven participants - five students pursuing M.S. or Ph.D. degrees in the area of information systems, plus the two participants from the individual studies. The number of participants was dictated by the number of students available who had completed at least one course that required projects using OO analysis, design, and programming. The substantive contributions provided by each participant during the GSS session suggests that they were familiar and comfortable enough with OO techniques to test the usefulness of a GSS approach in this setting.

We deliberately chose to include both participants from the individual studies in the group study. By comparing their individual responses to their responses in the GSS session, we were able to determine what was being lost in individual contributions to take advantage of the efficiency and flexibility of the GSS technology.

The individual studies were conducted first and separated from the group study by two months. This separation between studies was the result of the time needed to code the individual data and to develop and test the group procedures.

The GSS study was conducted using the VisionQuest software developed by Collaborative Technologies Corporation. VisionQuest runs under the MS-DOS operating system over a local area network. The room in which the study was conducted consists of eight straight rows of five microcomputers per row and a public viewing screen. The configuration allows both verbal and
electronic interaction and is consistent with the computer-based requirements that have been identified to support cognitive mapping [20, 28]. Verbal interaction between participants is valuable for suggesting further explanations of ideas and opinions. For example, a participant might verbally ask for an explanation of a concept, ask whether two concepts are similar and should be combined, or suggest why he or she feels a concept is important.

**EVOLUTION AND CONDUCT OF THE GSS APPROACH**

**Individual Studies**

We began with two individual studies to determine the feasibility of using cognitive mapping techniques for investigating perceptions of OO system complexity. The intent was to integrate the individual studies via a Delphi panel with iterative voting, in order to reach group consensus on category definitions and category importance rankings. The discovered categories would provide a common basis for identifying relationships which would result in a group cognitive map. Both individual studies consisted of the following steps to discover cognitive maps:

1. Self-questioning to determine concepts that make an OO system complex.
2. Grouping the concepts from self-questioning into categories.
3. Developing or defining the categories.
4. Ranking the categories by importance to OO system complexity.
5. Determining relationships between categories.

A modification of the Self-Q Technique [5, 6, 7, 8] was employed for eliciting the concepts that contribute to the complexity of OO systems. The Self-Q technique is designed to minimize researcher bias by having the participants ask themselves questions and thus determine for themselves what concepts they associate with the domain. The researcher provides only pre-written instructions and does not participate in discussing or determining the concepts and categories.

The Self-Q technique uses a framing statement and stall diagram. The framing statement is read by participants and is intended to set the stage for self-questioning and provide the subject with enough information to begin the self-questioning process. During the self-questioning process, participants may not always be able to think of a question to ask themselves. The stall diagram is intended to be used by participants to cue themselves to ask additional questions. The stall diagram depicts generic elements and characteristics of OO systems. Looking at this diagram cues participants to think about concepts
that pertain to the complexity of OO systems. Participants in the individual and group studies used the framing statement and stall diagram presented in Figure 2.

Insert Figure 2.

Instead of having the participants group concepts into Important/Not-Important categories as suggested by the Self-Q technique, participants were asked to group concepts into categories by their similarity. After the categorizing process was complete, the participants named and defined the categories. The primary difference between the first and second individual studies was in the self-questioning step. In the first study, the questions asked by the participant were hand-recorded and later coded by the researcher as described in [5]. This approach was cumbersome since the participant often repeated questions while the researcher tried to record them, or asked more questions than the researcher could record during the interview. Some information was lost because hand recording was slow.

In the second study, the participant was audio taped during the self-questioning process. This process is similar to talk aloud protocols used in other studies involving perceptions [23]. Additionally, in the second study the participant could both ask and answer questions. The tape was then transcribed and coded using content analysis [34]. These modifications - answering as well as asking questions, and audio-taping rather than hand-recording - increased the number of concepts identified in the second individual study (by 64%), even though the time spent in the self-questioning step was only 70% of the time involved in the self-questioning step of the first study. In other words, more concepts were identified in less time using the audio-taped versus the hand-recorded approach. It is not clear whether this difference is due to changes in the instructions, the recording technique, the coding technique, or differences in the participants. However, the question-and-answer transcript from the audio-taped session consisted of over 5000 words and the 54 questions from the hand-recorded session totaled less than 500 words. This indicates that the selection of data recording technique appears to have some influence over the amount of data captured. This is consistent with claims presented by other researchers [22].

The remaining steps in the individual studies were consistent across both studies. In steps 2 and 3, the participant placed 3X5 cards representing the concepts identified as important to OO system complexity in categories based on the similarity of the concepts, i.e., concepts perceived to be similar
were placed in the same category. The participant then named and provided a definition for each category. This categorization step provides a concept reduction technique that allows the responses of multiple participants to be combined at a higher level than that of individual concepts [43]. A more comprehensive representation of the participant's view of OO system complexity is expected to result from this category focus, versus the original Self-Q technique of selecting the ten or fifteen concepts ranked most important by the participant. The improvement in the representation is expected because of the potential for some categories to be excluded using the Self-Q Technique. For example, if more than one of the top ten concepts comes from a single category then concepts from another category may not be included. At the extreme, all of the top ten concepts could come from a single category, thereby excluding all others. A focus on categories reduces the potential for excluding information and should lead to a more detailed representation of the participants' perceptions. In step 4, the participants ranked the categories in order of their perception of the contribution the category makes to OO system complexity. In the last step, 3x5 cards showing the category names were arranged in a circle and the participants indicated their perceptions of causal relationships between the categories.

**Exploration of Group Methods**

Following the two individual studies, the researchers attempted to design a method that would combine individual responses into a group cognitive map to show shared concepts. A three-step Delphi panel process [13] was designed to reach consensus on the categories and their importance. Relationships between categories would then be identified by each participant. This definition of a shared meaning for the categories is important for the derivation of a group map, since without a shared meaning, the maps of the multiple participants cannot be compared [8, 35].

An interview script was developed that detailed the steps required to derive a group cognitive map. The script proposed a series of six interviews that combined the procedures of the Self-Q technique (used in the individual studies) with procedures of the Delphi panel process. The large number of interviews was necessary to achieve the desired level of agreement on the categories and their definitions. In essence, each individual would be reacting to the perceptions of the other participants. An estimate of the time required of each participant in a group study was prepared. The time required to complete the Self-Q technique in the two individual studies averaged two hours and thirty minutes. An estimate of the time required for a participant to complete the series of Delphi panel rounds was prepared by timing a researcher attempting the procedures. This resulted in an estimate of one hour and twenty minutes for the three Delphi panel rounds. Combining the two estimates resulted
in an estimate of three hours and fifty minutes of time commitment from each participant in a group study. The meetings were to be spread over a two-month period to provide time for coding of the transcripts and coordination of the Delphi panel process. The agreed-on set of categories from the Delphi panel would provide the basis for a cognitive map representing the group's perceptions. While this process may seem reasonable, substantial problems remained.

The time and number of planned meetings required to complete a group study was substantial. Professionals who were using OO techniques were contacted as potential participants in a group study. They indicated that the time and number of meetings were beyond what they were willing to commit. For a study of 7 participants, the time and effort required of the researchers to transcribe, code, prepare, coordinate, and conduct the interviews, was estimated to be approximately 140 hours (28 interview hours, 35 hours of transcription, and 77 hours of coding). Potentially, forty-two separate interviews might be needed. The proposed plan was unreasonable from the perspective of potential participants and economically infeasible from the perspective of the researchers. Clearly, we needed a way to reduce the time and effort required of participants and researchers. The researchers turned to group support systems as a means by which to solve this dilemma.

**GSS Approach**

VisionQuest uses the concept of a dialogue to structure group decision making. A dialogue consists of a coordinator, an agenda, and a list of participants. The agenda is simply a list of tools to be used by the group in structuring their interaction. The dialogue coordinator determines which VisionQuest tools will be used to put together the agenda, depending on the nature of the task. Examples of tools that might be included in an agenda are electronic brainstorming, point allocation, voting, and ranking. Like most GSSs of its type, VisionQuest allows participants to enter their ideas simultaneously and anonymously. Individual inputs can be aggregated and displayed on the public screen.

The steps in the proposed group interview script were compared to the tool set of the VisionQuest GSS software. The instructions from each step in the interview script were easily adapted to the GSS environment. The resulting GSS agenda included the ability to develop a set of agreed-on categories as the basis for the group cognitive map. This could be done with participants attending a single half-day meeting, as opposed to the months of coordinated meetings envisioned earlier, resulting in a considerable savings of researcher time and effort.
The procedures of the GSS approach for investigating perceptions of OO system complexity match well with both the individual studies and the group interview script. A test of a preliminary version of the GSS approach was conducted with four Information Systems faculty members and three Information Systems doctoral students. The faculty members had published in the areas of GSS and OO techniques. The doctoral students had completed a course that required using OO techniques. The test session included following all procedures and agendas; it resulted in improvements, including revised instruction wording and adding labels to the stall diagram. Two weeks later, the actual study of the GSS approach was conducted with the seven participants described earlier. Table I shows the steps in the GSS session, including a brief activity description, the time required for each step, the data collected, and the VisionQuest tool used for each activity. In addition to the participant input that was captured by the logging program of the VisionQuest software, the session was audio-taped to provide additional documentation of the timing of exercises, category definitions, and the activities of the facilitator (one of the authors). Throughout the session, the facilitator provided procedural guidance only, e.g., administrative activities such as reading instructions and keeping time. At no time did the facilitator provide feedback on group responses. Details of each GSS activity follow.

Introduction The meeting began with a 30-minute introduction of the facilitator and participants. The participants were trained on the GSS software, using a task of identifying preferred pizza toppings. The purpose and domain of the study were presented using the framing statement and stall diagram shown in Figure 2.

Concept Identification This activity was supported using a Brainwriting exercise. Brainwriting is a VisionQuest tool that implements electronic brainstorming by allowing each participant to privately key in comments, which are then displayed on a public screen. The purpose was to determine the concepts that relate to OO system complexity. Participants were asked to generate items that represented characteristics, concepts, or issues they believed contributed to OO system complexity. The framing statement presented in Figure 2 was the question asked of participants. All alternatives were shared among the participants by being displayed on the public and individual screens.
**Category Identification**  The purpose of this activity was to determine a set of categories, including definitions, that contain the set of concepts developed in the previous activity. This activity was supported with a combination of Brainwriting and Compactor tools. The Compactor is a tool in the VisionQuest software that supports the process of converging from a large number of concepts into a smaller set of categories. This process requires that category definitions be specified before concepts are placed into categories by participants. The categories and their definitions would then be used for the next activity where participants place the concepts into the categories.

Participants viewed the concepts from the previous Brainwriting exercise and verbally suggested categories. The facilitator wrote the group's suggested category names on a chalkboard and revised them until the group reached agreement. Agreement was defined by there being no further comments on the list of categories when participants were asked to add to, modify, or delete categories on the list. Category identification was done verbally rather than through the GSS tools because verbal interaction seemed more efficient in this case, as several additional agenda items would be required to accomplish this goal. The facilitator recorded the categories and definitions, as agreed on by the participants, in the Compactor tool.

**Concept Categorization**  This 45-minute process attempted to validate the categories identified. This activity was supported with the Compactor tool. The categories identified in the previous step were used to group the items from the concept identification step. Each participant placed each concept into one of the categories based on the similarity of the concept to the category definition and to other concepts placed in the category by that participant. The final group results were displayed on the public screen. If most of the concepts fit well into a category, i.e., were placed in that category by a majority of participants (four or more), then face validity for the categories as a set is increased. In other words, there would appear to be agreement on the meanings of the concepts and the categories.

**Category Rating**  The purpose of this activity was to determine the amount of consensus on the relative importance of the categories. This activity was supported using the Rating tool, with three ratings rounds intended to be the equivalent of a Delphi panel process. Ratings were measures of the importance of a category to OO system complexity on a scale of 1 (important) to 7 (extremely important). This scale is appropriate since the categories are derived from the "important" concepts and therefore a scale anchored with "not important" is likely only to compress ratings into the upper portions of the scale. The participants rated each of the categories individually and the mean ratings were then discussed after the round. Another rating exercise was conducted with the group results of
the first rating exercise displayed on the public screen. The discussion and rating steps then were performed a final time.

**Relationship Identification** Relationships were identified using an influence matrix implemented using the VisionQuest Scoring tool. Participants rated each cell in the matrix on a scale showing the influence of the category in each row on the category in each column. The rating scale ranged from a strongly negative influence (-3) to a strongly positive influence (+3), but was entered by the participants using a 1 to 7 scale provided by the Scoring tool. The "no influence" response was a 0, which was also the default cell value. These relationships provided the final component required to produce a cognitive map of the group's perceptions of OO system complexity.

**COMPARISON OF THE INDIVIDUAL AND THE GSS STUDIES**

Table II presents a comparison of the GSS and the individual studies. The table shows that the GSS procedures provide the data necessary to uncover a cause map of perceptions of OO system complexity consistent with data produced by similar individual procedures. Details on each data collection and analysis activity follow.

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**Concept Identification** Data collected in this step provided the foundation for the remaining steps. Concepts represent the perceptions of complexity of the object or process under study, in this case an OO system. The comprehensiveness of the identified concepts demonstrates the effectiveness of this GSS activity for achieving the objective of eliciting/identifying concepts -- an objective that is fundamental to cognitive mapping techniques. The breadth and depth of concepts identified are indications of the face validity of the GSS approach.

In the 30-minute brainwriting session that was used for this step, 148 concepts were identified. The concepts identified were associated with many characteristics commonly defined by researchers in the area of OO systems, including inheritance, polymorphism, encapsulation, items internal to individual methods and objects, items associated with the interrelatedness of methods and objects, and management of the OO development process [3, 10, 11].

The 148 concepts identified were compared with the concepts identified in the individual studies. The first individual identified 93 concepts in the hand-recorded 50-minute session.
Transcription and coding revealed the 154 concepts identified by the second individual in the 30-minute tape-recorded self-questioning session. Fewer concepts were identified per participant using the GSS approach, averaging 21 concepts per participant with a range of 9 to 38. The participant from the first individual session identified 23 concepts in the group session - 24% of the number defined in the individual session. The participant from the second individual study identified 38 concepts in the group session or 25% of the 154 identified in the individual session. Concerns raised by the substantially lower numbers of concepts identified by the individuals in the GSS session are offset somewhat by comparing the concepts identified in the individual studies and the concepts identified using the GSS approach.

The concepts were compared using a content analysis technique [34]. Using this approach, many concepts identified in the individual sessions were identified in the group session. Table III shows that many of the concepts identified in the individual studies and also identified in the group session were provided by group members other than the participant from the individual study. For example, the group identified 44 of the 93 concepts (47%) from the first individual study. Of these 44 concepts, 17 were matched by concepts identified during the GSS session by the participant from the first individual study. Thus, other group members identified the other 27 concepts that matched responses from the first individual study. This indicates that group members, other than the participant from the individual study, provided concepts consistent with the results of the individual study. Additionally, the 17 individual study concepts were matched by only 6 - of the 23 - group study concepts identified by this individual, indicating that some redundancy exists in the data from the individual study. Thus, 74% (17/23) of the concepts this individual identified in the GSS session did not map to one of the 93 concepts identified by this participant in the first individual study. Similar findings exist for the participant from the second individual study. The group identified 84 of the 154 concepts (55%); of these 84 concepts, 44 were matched by concepts identified by the participant from the second individual study during the GSS session. However, these 44 individual study concepts were matched by only 19 of the 38 concepts identified by this individual in the group study. This means that 50% (19/38) of the concepts this individual identified in the GSS session did not map to one of the 154 concepts identified in the second individual study. This analysis indicates that a substantial portion of the group's concepts that match concepts from the individual studies came from group members other than the individual study participants. It also suggests that data from the individual studies are repetitious.
The overlap of concepts identified by the different techniques is not expected to be exact. For example, if the participant from the second individual study identified the average number of concepts in the GSS session, in this case 21, and each of those concepts was one of the concepts also identified in the individual study, then we would expect that 14% (21/154) of the concepts identified in the individual study would also be identified in the GSS study by that individual. This statement assumes that only the participant from the individual study would identify similar concepts in the GSS session. The high percentages presented above serve to reject this assumption by showing that other participants, i.e., not those that participated in the individual studies, identified substantial percentages (61% & 48% respectively) of the concepts from the individual studies. This finding may indicate why there were fewer concepts identified by participants in the GSS session versus the individual studies. When a participant from one of the individual studies looked at the concepts input by others during the group study, many of them may have seemed familiar. We speculate that it was not necessary to input those concepts that seemed familiar resulting in an automatic elimination of redundancy due to the GSS environment. It may also be that reading others' concepts and typing your own concepts requires more effort per concept than generating concepts verbally. When asked about the differences between the concept identification steps of the individual and GSS approaches the participants supported these speculations, although it should be noted that this question was asked nine months after the GSS study and almost a year after the individual studies and thus is speculative.

The overlap of concepts identified by the group and individuals is an indication of the consistency of the GSS approach and the procedures used in the individual studies. Failing to overlap at least 14%, i.e., 1/7, of the concepts from an individual study would be a direct contradiction of the usefulness of the GSS approach, especially given that the participants from the individual studies were also GSS participants. The 83 concepts identified by the group that do not overlap with individual concepts represent an enhancement to the individual results. The degree of overlap identified supports the use of GSS technology for eliciting concepts required as a basis for uncovering cognitive maps.

**Category Identification** Identifying categories was part of the concept refinement process of the individual cognitive mapping studies. However, in the individual studies the naming and definition process occurred after the categorization of the concepts. In the GSS environment, it was necessary for
the group to agree on the categories and definitions before categorization could occur. In other words, the group needed to develop shared meanings for the categories to be able to place concepts in the categories. Table IV shows the categories and definitions determined by the group.

Determination of individual categories that matched group categories was accomplished using content analysis. The concepts in each individual category that matched with a group concept were evaluated to determine the group category to which they belonged. If the concepts in an individual category were mostly from one group category, i.e., a majority of the concepts in a given individual category corresponded with concepts in one group category, then the individual category was said to match the group category. In addition, the definitions provided by the individuals for their categories were compared to the matched group category definitions. The categories identified with the GSS approach were consistent with those identified in the individual cognitive mapping sessions.

The first individual study participant identified 11 categories that grouped the 93 hand-recorded concepts by similarity. The second participant identified 16 categories that grouped the 154 concepts from the taped session by similarity. Together, this resulted in 14 unique categories. The group identified 9 of these 14 (60%) categories. The individuals identified all the same categories as the group except "maintenance." Although the individuals did not specify a maintenance category per se, both participants identified concepts that note maintenance explicitly. Five group categories, i.e., "structure," "method design," "message passing," "problem domain," and "reusability," were identified by both individuals. In addition to these categories, the first individual also identified "class design" and "solution domain," and the second individual also identified the "project management" and "methodology/tools" categories. Only five categories identified by the individuals could not be mapped to categories defined by the group. These categories were "persistence," "protocol," "global variables," "data types," and "class specification."

Due to the idiosyncratic nature of cognitive maps [12, 21] and the difficulties of creating shared cognitive maps [8, 35], the 60% consistency of the categories identified by the individuals and the group represents moderate support for the use of GSS technology for this type of concept-refinement step.

**Concept Categorization** Validation of the categories consisted of the participants placing the concepts into the categories. The number of concept categorizations that were agreed upon by a majority of
participants and the overall agreement in the categorization process provided support for the validity of
the categories. Low levels of agreement would have suggested that the categories and/or concepts did
not have shared meanings or that the set of categories was incomplete.

Measures of group agreement were calculated for the categorizations of all concepts and each
individual concept. High levels of agreement - six or more participants - existed on 40% (59) of the
concepts. Most concepts - 73% (108) - were placed in one of the ten categories by four or more
participants. Only four of the 148 concepts were not assigned to some category by all participants. The
overall K, Kappa, for all concepts score is .50, indicating a moderate level of agreement about the overall
categorization of concepts within the group [45]. This result is significantly different from zero
agreement, with a calculated Z=69.23, p < .001, suggesting that the categories were valid from the
perspective of the participants.

Concepts placed in each category were consistent with the definitions determined by the group
during the session. This is an indication of internal validity of the experiment, i.e., the participants
accomplished the assigned task and grouped similar concepts based on the definitions.

The analyses presented provide a validated set of categories with their accompanying concepts.
The ability to support this category definition and verification process is essential for use of the GSS
approach as a basis for a group cognitive map. In other words, a cognitive map showing relationships
between nodes with unknown meanings is likely to be of little value for understanding an object or
process.

**Category Importance** Determination of the relative importance of the categories is another common
refinement step in cognitive mapping procedures [5, 6, 7]. GSS are especially designed to facilitate this
type of exercise. Table V shows the means and standard deviations of the category importance ratings
for each of the three successive rating steps. Also presented is the amount of group agreement at each
step.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std Dev</th>
<th>Group Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 2</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Step 3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The measures of group agreement, pertaining to the relative importance of the categories, show
that each step increased the agreement among the participants, ultimately reaching a moderately high
(.70) level of agreement. This is an indication of internal validity. The standard deviations for eight of
the ten categories were reduced over the three steps with all final values under 1.7 and five values under 1.00, providing additional evidence of the convergence of opinions among the participants.

Mean ratings from the first to the second step were similar, as were the mean ratings from the second to the third step. This indicated that mean category importance ratings were consistent over the rating steps. Rankings of the first six categories were unchanged over all three rating steps. Potentially, a single rating step may further reduce costs of developing group cognitive maps using the GSS approach.

In the individual cognitive mapping studies discussed above, category importance was determined by ranking the categories in order of importance. Comparison of the individual category rankings to the rankings created from group ratings is possible for the overlapping categories of each individual. The rankings provided by the individuals generally agreed with the ranking provided by the group. The Kendall coefficient of concordance shows significant agreement in the overlapping category rankings of the first individual and the group (excluding the first individual -- to provide a greater degree of independence between the group and individual results), $W = .94$, $p < .05$, and for the second individual and the group (excluding the second individual) $W = .89$, $p < .10$. Both of these values show high levels of agreement with the group pertaining to the relative importance of the categories to OO system complexity.

The category refinement step of the GSS approach provides a rationale for the development of reduced models from data provided by the participants. Potentially the most important categories could be evaluated to reduce the costs of investigation. High levels of agreement with the individual rankings for overlapping categories provides additional support for the GSS approach.

**Relationship Identification** The final component required to derive a cause map of group perceptions of OO system complexity is the relationships between the categories. Individual group member relationship identifications were collected without seeing other participants' responses, i.e., the public screen was not used. The average number of relationships identified by participants was 63 (of the 90 one-way relationships possible) and ranged from 38 to 78. Combining these relationships is possible due to the shared meanings established for the categories and provides the basis for discovering a group cognitive map.

The GSS approach incorporates the idea of "levels of agreement" into the analysis of cognitive maps. Levels of agreement refers to the idea that there are some relationships and directional effects (positive or negative influence) that all participants agree exist. Relationships of this type might be seen
as representing "perfect agreement." In the current study, perfect agreement would exist for relationships that all seven participants independently identified as having the same direction. Such a map is created by the evaluation of each possible link in the cognitive map to determine its level of agreement, including the number of participants that said the link exists, the number of participants that said a positive effect exists, and the number of participants that said a negative effect exists. Thus, cognitive maps representing different levels of agreement may be represented by selecting a relationship-exists-value and a direction-exists-value. Beginning with the relationships identified as "perfect agreement" and progressively adding less agreed-on relationships provides a technique for observing the "emergence" of the complexity of the group cognitive map. In other words, as less agreement is required to add a relationship to the map, more relationships qualify to be added; as more relationships are added, the complexity of the object or process the map represents becomes more apparent.

A series of maps representing different levels of agreement, in this case, 7-6-5-4, were analyzed. Figure 3 shows the group cognitive map resulting from this step where at least five participants identified the relationship and the direction of the relationship. At least five members of the group identified the respective relationships (relationship-exist-value ≥ 5) and at least five members of the group agreed on the direction of the effect (direction-exist-value ≥ 5). The map where five participants agreed represents a majority of the participants and shows the usefulness of the resulting maps. The arrow indicating that a relationship exists shows that participants perceived that an increase in the complexity of the originating category affects the complexity of the terminating category. The direction of the effect, increase or decrease in the complexity of the terminating category, is shown with + or - signs respectively. Only one decreasing relationship was identified. This may be due to the statement used to determine relationships. Participants were asked to determine if "an increase in the complexity of category A (increases or decreases) the complexity of category B?" Presumably, either positive relationships are the easiest for the participants to process mentally or the categories are actually positively related.

--------------------------------------------------------------------

Insert Figure 3.

--------------------------------------------------------------------

Since our goal is to demonstrate the feasibility of the GSS methodology vis-a-vis individual cognitive mapping techniques, the specific technique used to derive the group map is not critical.
Indeed, the preparation of maps utilizing techniques defined in previous research [5, 50, 52, 53] from the data provided seem appropriate for providing additional analyses of the group's perceptions and evidence of the usefulness of the GSS approach.

Figure 3 shows the representation used by the group to view the complexity of OO systems. It appears that an increase in the complexity of structure, maintenance issues, and reusability concerns makes the development process (class design, method design, message passing, and project management) more complex. This direction of causality through the map was supported by analysis of the ratio of in-flows and out-flows of each node to show causal flow in a cognitive map [22]. In Figure 3, the ratio of in-flows to out-flows for each node increases from left to right showing the direction of causation in the cognitive map. In other words, the group sees the complexity of the problem through the existing structure and uses the development process to control the complexity involved in the problem domain.

This description also makes sense when evaluated using givens, means, and ends analysis [50]. Givens are defined as having mostly out-flows and ends as having mostly in-flows, while means have about equal in-flows and out-flows. Applied to Figure 3, this analysis shows that givens consist of the existing inheritance structure, maintenance issues, and reusability concerns. These givens provide inputs to means required to develop the system, which consist of class design, method design, message passing, and project management. These means are used to accomplish the ends of creating an appropriate solution domain and an effective implementation of the problem domain. In addition, the ratio of relationships to categories (links to nodes) is 3.1, indicating the group perceives many possible ways to manage complexity in an OO system. This is a plausible interpretation that shows the usefulness of the data produced by the GSS approach.

The cognitive maps from the individual studies also were consistent with the group cognitive map. Comparing individual and group maps based on the overlapping categories was revealing. The first individual identified 82% (9/11) of the links identified by the group for those categories and only three links not identified by the group. The individual in the second study identified 75% (6/8) of the links identified by the group for those categories and only two links not identified by the group. This high percentage of matches with the group map and low number of idiosyncratic links shows a high degree of overlap in the relationships perceived between the categories. This overlap is an indication of the consistency of the cognitive maps developed using the individual techniques and the GSS approach and provides evidence of the GSS approach as a viable alternative to the individual techniques.
SUMMARY AND CONCLUSIONS

The GSS session conducted in this study shows that it is possible to use a GSS approach to derive cognitive maps. The procedures defined provide for eliciting concepts, refining concepts, and identifying relationships between concepts -- steps common to many cognitive mapping techniques. The identification of 148 concepts and 10 categories that group the concepts by similarity are indications of the comprehensiveness of the concepts and the existence of categories. The ability of the approach to produce these results is the first level of support for its effectiveness. The consistency of each step in the agenda with the individual mapping procedures provides support for the validity of the GSS approach. The reliability of the GSS procedures should be high due to the detailed documentation of facilitator procedures and the consistency between sessions provided by the software. The identification of concepts in the group session that were not identified in the individual sessions provides support for the GSS approach as an aid to idea stimulation, although it is possible that studying each member of the group individually would have produced all the group concepts.

The GSS approach to cognitive mapping provides data to support the development of models to guide future investigations including the suggestion of constructs, propositions, and a starting point for measures. In other words, the categories and concepts form an ideal basis for instrument development, e.g., a survey could be developed from the most agreed-on concepts in the most important categories. A great deal of time and effort are spent by researchers on the task of instrument development. The ability of the methodology to provide support for this activity is additional evidence of the value of the GSS approach.

Efficiency of the procedures versus other cognitive mapping techniques is another reason to consider the use of a GSS approach. This is especially true in the determination of concise group perceptions based on agreed categories. The type of computer classroom facility used in the GSS approach is available at many universities. The creation of a research tool through the acquisition of GSS software for an existing facility is appealing to both researchers and administrators.

The methodology developed in this paper is subject to several limitations, however. Small sample sizes preclude applying multivariate statistical techniques to the data. Sufficient data to complete a rigorous factor analysis did not exist. At least 50 subjects are necessary when 10 categories are used. The physical facilities to conduct a GSS session with 50 participants are available, but finding that many qualified and willing participants is a limiting factor. In addition, the effects of large group
size on participation may influence the results. Multiple GSS sessions could be run to obtain larger samples, but all groups in the multiple sessions would have to identify the same categories. Such consistency is unlikely to happen by chance. The alternative is to impose categories or concepts on the multiple groups a priori -- a practice that is inherently contradictory to the goal of uncovering participants' own perceptions. These issues lead to rejection of factor analysis as an appropriate statistical approach for analysis of these data. Intensive research techniques such as this approach are normally associated with qualitative data analysis techniques.

Another limitation is that only one GSS-supported study has been conducted. A causal model based on this single session may be suspect. To address this limitation, a series of GSS sessions could be conducted in a manner similar to that of multiple experiments in the natural science model. This idea is consistent with suggestions for the use of case studies for similar purposes [51].

The variety and results of the analyses performed on the data from this activity provide support for the potential of the GSS approach to address consensus verification, category validation, and construct identification. These are essential ingredients for the development of models of group perceptions. The potential benefits and flexibility of the GSS approach may encourage the use of cognitive mapping as a research methodology for the study of perceptions of complexity of other tasks.

This study provides a wealth of opportunities for future research involving GSS cognitive mapping and the study of perceptions of complexity. Given the consistency of the steps in the GSS agenda with the individual techniques, application of the GSS approach to cognitive mapping for other problems seems appropriate. Potentially, questions can be addressed by providing an appropriate framing statement and modifying agenda instructions based on the nature of the research. This methodology accomplishes the objectives of cognitive mapping and brings analyses of agreement together with the identification of causal constructs. The methodology is particularly valuable for the efficient investigation of previously unexplored areas. However, concepts and categories may be provided in advance with the goal of verifying or falsifying the existence of theoretical constructs.

Further validation of the methodology also is necessary. For example, using the GSS methodology to measure the effects learning has on perceptions of complexity, e.g., novice versus expert perceptions, should produce results consistent with other studies of novice and expert perceptions.

A number of interesting research questions remain to be answered. First, can the results of this study be replicated in another GSS session with different group members? Second, can the results of this study be replicated using other research methods, such as surveys or paired comparisons of OO
systems? Third, can the GSS approach be validated through replication of previous cognitive mapping studies? These questions suggest a fertile ground for continuing research and discovery in the area of GSS applications, complexity, cognitive maps, and OO systems.

REFERENCES:


<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Duration</th>
<th>Results</th>
<th>VisionQuest Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eliciting Concepts</strong></td>
<td>System use, informed, consent form, framing statement, and stall diagram.</td>
<td>30 minutes</td>
<td>10 Descriptive Questions Answered</td>
<td>Comment Cards and Brainwriting</td>
</tr>
<tr>
<td>Introduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concept Identification</td>
<td>Elicit characteristics, concepts, or issues that contribute to (increase or decrease) the complexity of an OO system.</td>
<td>30 minutes</td>
<td>148 Concepts</td>
<td>Brainwriting</td>
</tr>
<tr>
<td><strong>Refining Concepts</strong></td>
<td>Elicit categories that organize the list of concepts by similarity. Agree on definitions and names.</td>
<td>30 minutes</td>
<td>10 Categories</td>
<td>Verbal for Participants, Facilitator uses Compactor</td>
</tr>
<tr>
<td>Category Identification</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concept Categorizations</td>
<td>Participants place the concepts into the top ten categories.</td>
<td>45 minutes</td>
<td>10 Categories, 4 Concepts Unassigned</td>
<td>Compactor</td>
</tr>
<tr>
<td>Discussion of Concept Categorizations</td>
<td>Participants discuss placements.</td>
<td>10 minutes</td>
<td>118 Agree, 30 Disagree</td>
<td>Compactor</td>
</tr>
<tr>
<td>Category Rating Step 1</td>
<td>Participants rate each category on a seven point scale from important to extremely important.</td>
<td>5 minutes</td>
<td>Ranking of Categories</td>
<td>Rating</td>
</tr>
<tr>
<td>Discussion of Category Ratings</td>
<td>Group means are calculated and discussed.</td>
<td>15 minutes</td>
<td>Discussion of Agreement</td>
<td>Verbal Discussion</td>
</tr>
<tr>
<td>Category Rating Step 2</td>
<td>Participants rate each category on a seven point scale from important to extremely important.</td>
<td>5 minutes</td>
<td>New Ranking of Categories</td>
<td>Rating</td>
</tr>
<tr>
<td>Discussion of Category Ratings</td>
<td>Group means are calculated and discussed.</td>
<td>15 minutes</td>
<td>Discussion of Agreement</td>
<td>Verbal Discussion</td>
</tr>
<tr>
<td>Category Rating Step 3</td>
<td>Participants rate each category on a seven point scale from important to extremely important.</td>
<td>5 minutes</td>
<td>New Ranking of Categories</td>
<td>Rating</td>
</tr>
<tr>
<td>Relationship Identification</td>
<td>Participants are individually presented a comparison matrix of the categories in a rating task. Rating is on a scale of -3 to +3 from strongly negative influence to strongly positive influence of one category on another category.</td>
<td></td>
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<tr>
<td>-----------------------------</td>
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</tr>
<tr>
<td>Scoring</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>20 Agreed on Relationships</td>
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<td></td>
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</tr>
<tr>
<td>Scoring</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 Minutes</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>30 Minutes</td>
<td></td>
<td></td>
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<tr>
<td>Scoring</td>
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<td></td>
</tr>
<tr>
<td>50 Comments</td>
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<tr>
<td>Scoring</td>
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<tr>
<td>50 Comments</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Debriefing</th>
<th>Participants enter comments on the GSS procedures and results of the process.</th>
<th>10 Minutes</th>
<th>50 Comments</th>
<th>Comment Cards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debriefing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

-------------------------------------------------------------------------------
Table 2  Comparison of GSS and Individual Approaches

<table>
<thead>
<tr>
<th>Step/Procedure</th>
<th>Data Provided By Group</th>
<th>Data Provided By Individuals</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept Identification</td>
<td>148 Concepts</td>
<td>247 total concepts,</td>
<td>Overlap of concepts, but with a majority of group concepts not identified by the individuals and a substantial number of individual concepts not identified by the group.</td>
</tr>
<tr>
<td></td>
<td>51 Match Individuals</td>
<td>85 for individual 1,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>44 match group,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>154 for individual 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>84 match group.</td>
<td></td>
</tr>
<tr>
<td>Category Identification</td>
<td>10 Categories</td>
<td>14 unique categories,</td>
<td>Majority of individual concepts overlap with concepts identified by the group.</td>
</tr>
<tr>
<td></td>
<td>9 Match Individuals</td>
<td>11 for individual 1,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7 match group,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>16 for individual 2,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7 match group.</td>
<td></td>
</tr>
<tr>
<td>Concept Categorization</td>
<td>Concepts in Categories</td>
<td>Concepts in Categories</td>
<td>Associated group and individual concepts and concept categorizations used to determine category equivalence.</td>
</tr>
<tr>
<td>Category Ranking</td>
<td>Ratings of Category Importance Converted to Ranking</td>
<td>Categories Ranked by Importance</td>
<td>Significant agreement of ranking of overlapping categories.</td>
</tr>
<tr>
<td>Relationship Identification</td>
<td>Direction and Magnitude of Relationships</td>
<td>Direction of relationships for overlapping categories</td>
<td>Consistency between relationships identified by the group and individuals for overlapping categories.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>75% individual 1 match group,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>75% individual 2 match group</td>
<td></td>
</tr>
<tr>
<td>Construct Identification</td>
<td>Givens, means, ends, analysis, Cluster Analysis</td>
<td>Givens, means, ends analysis.</td>
<td>Organization of overlapping categories into similar clusters with givens, means, ends analysis. Cluster analysis of group data supports givens to ends analysis.</td>
</tr>
</tbody>
</table>
Table 3  Concepts from Individual Studies that Matched Concepts from the GSS Study

<table>
<thead>
<tr>
<th>Study</th>
<th>Number of Concepts Identified in the Individual Study</th>
<th>Matching Concepts from the GSS Study. (%) percentage of Individual Concepts Matched</th>
<th>Concepts Matched By Individual in the GSS Study</th>
<th>Concepts Matched By Others in the GSS Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Individual Study</td>
<td>93</td>
<td>44 (47%)</td>
<td>17</td>
<td>27</td>
</tr>
<tr>
<td>Second Individual Study</td>
<td>154</td>
<td>84 (55%)</td>
<td>44</td>
<td>40</td>
</tr>
<tr>
<td>Category Name (Code)</td>
<td>Definition</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>---------------------</td>
<td>------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class Design (CD)</td>
<td>Encapsulation, intra class complexity, proper placement of methods and attributes, choice of class protocol. Labels or names of attributes and methods. Number of attributes, etc. Use of global variables, polymorphism, or information hiding.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance (MA)</td>
<td>Modification after release.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Method Design (MD)</td>
<td>The length of the method in lines of code, number of arguments, and placement of methods in the appropriate classes within the class hierarchy.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methodology/Tools (MT)</td>
<td>The analysis and design notation, debugging and navigation tools, etc. Testing tools, documentation, general programming tools.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Problem Domain (PD)</td>
<td>Constraints within the domain. Clarity of the requirements document. Interpretation of the problem domain, have you covered all the domain. Stability of the problem. How this domain fits into future problem domains.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Management (PM)</td>
<td>Project management constraints, people management, choice of standards, consistency of conventions, and selection of methodologies and tools.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reusability (RE)</td>
<td>Reusing existing stuff in this application.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solution Domain (SD)</td>
<td>Graphical user interface, programming language, platform (hardware and software), and network.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structure (ST)</td>
<td>Relationships between classes, objects, and instances. The static structure of the system. Includes &quot;a kind of&quot; and &quot;a part of&quot; structures.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 5 Categories and Mean Ratings of Importance

<table>
<thead>
<tr>
<th>Category Name</th>
<th>Number of Concepts</th>
<th>Means Rating 1</th>
<th>Std. Dev. 1</th>
<th>Means Rating 2</th>
<th>Std. Dev. 2</th>
<th>Means Rating 3</th>
<th>Std. Dev. 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class Design</td>
<td>49</td>
<td>6.29</td>
<td>0.76</td>
<td>6.57</td>
<td>0.54</td>
<td>7.00</td>
<td>0.00</td>
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<tr>
<td>Structure</td>
<td>43</td>
<td>6.14</td>
<td>0.69</td>
<td>6.29</td>
<td>0.76</td>
<td>6.57</td>
<td>0.78</td>
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<tr>
<td>Problem Domain</td>
<td>21</td>
<td>6.14</td>
<td>1.22</td>
<td>6.29</td>
<td>0.76</td>
<td>6.14</td>
<td>0.38</td>
</tr>
<tr>
<td>Solution Domain</td>
<td>52</td>
<td>5.29</td>
<td>1.38</td>
<td>5.71</td>
<td>0.95</td>
<td>5.57</td>
<td>0.98</td>
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<tr>
<td>Message Passing</td>
<td>14</td>
<td>5.14</td>
<td>1.95</td>
<td>5.57</td>
<td>1.40</td>
<td>4.86</td>
<td>1.57</td>
</tr>
<tr>
<td>Method Design</td>
<td>32</td>
<td>4.86</td>
<td>1.57</td>
<td>4.86</td>
<td>1.07</td>
<td>4.86</td>
<td>0.90</td>
</tr>
<tr>
<td>Methodology/Tools</td>
<td>48</td>
<td>4.57</td>
<td>2.15</td>
<td>4.29</td>
<td>1.38</td>
<td>3.14</td>
<td>1.68</td>
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<tr>
<td>Reusability</td>
<td>22</td>
<td>4.00</td>
<td>2.08</td>
<td>3.57</td>
<td>1.27</td>
<td>4.43</td>
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<tr>
<td>Project Management</td>
<td>58</td>
<td>3.86</td>
<td>2.04</td>
<td>4.71</td>
<td>1.60</td>
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<td>1.57</td>
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<td>12</td>
<td>3.14</td>
<td>1.07</td>
<td>2.57</td>
<td>0.98</td>
<td>2.86</td>
<td>1.22</td>
</tr>
</tbody>
</table>

Group Agreement of Individuals

<table>
<thead>
<tr>
<th>Kendall Coef. of Concordance (W)</th>
<th>Rating 1</th>
<th>Rating 2</th>
<th>Rating 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.31</td>
<td>.59</td>
<td>.70</td>
</tr>
<tr>
<td>Significance</td>
<td>p &lt; .05</td>
<td>p &lt; .05</td>
<td>p &lt; .05</td>
</tr>
</tbody>
</table>

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Figure 1. Example of a Simple Cognitive Map (Text statements represent concepts in the cognitive map; arrows show the relationships between concepts; signs show the direction of the effect of the relationship. Adapted from [39])
Framing Statement

We are interested in both object systems and controlling the complexity of software. It would be useful to know what you believe contributes to (increases or decreases) object system complexity.