Using Concepts Maps to Improve Team's' Abilities to Navigation of Ill-Structured Problems

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ABSTRACT

Ill-structured problems are complex and often require a significant amount of domain knowledge to solve. Most problems in the field of User-Centered Design (UCD) fall into the classification of ill-structured. Due to frequently changing technologies, growing organizations, and inconsistent environmental factors there is often no one right path and one right solution for a given client. New professionals and students in the field of User Centered Design (UCD) struggle as they attempt to apply UCD concepts to tackle the ill-structured problems., There are few tools to aid them in acquiring this domain specific knowledge and promoting the higher order thinking necessary to navigate the ill-structured problems. In this study, an interaction model consisting of a concept map containing UCD methods was tested. The goal of the concept map interaction model was to help teams who are new to the UCD domain learn the necessary concepts and process which they may use to navigate ill-structured client problems. The study is a two-part study: The fist part consisted of usability testing of two interaction model designs; The second study used the improved interaction model and proposed an ill-structured problem to a newly formed team. It was found that teams responded to imposed structure which enable them to better navigate the given ill-structured problem. Though we gained only preliminary results, teams that had more structure and spent more time using the UCD interaction model were less likely to focus immediately on developing a final product. Additionally, the final product that these teams produced more closely resembled the final product of experts.

Keywords

Interaction model, concept map, knowledge representation, mental model, team, ill-structured problem.

INTRODUCTION

Most of us have had an encounter with a problem that did not appear to have any clear way of getting to a solution. Some of us encounter these in the workplace, others during education. These problems seem to have multiple correct answers and many ways to go about solving. An example would be any problem that has multiple correct solutions, similar to writing a paragraph or creating a picture. Sometimes we involve others in solving the problems we encounter due to the problem's complexity or our lack of knowledge on the subject. Our primary focus is on how teams navigate and resolve ill-structured problems. In relation to our research, we feel it is important to touch on key concepts a) the problem solving process in a team, b) knowledge representation, c) group communication, d) domain self-efficacy, and e) interaction models.

An ill-structured problem can be defined as complex problems, which have unclear goals, multiple solutions, and solution paths (Ge & Land, 2003; Jonassen, 1997). Additionally, ill-structured problems often take place in dynamic environments where the variables fluctuate (Jonassen, 1997). Navigating an ill-structured problem is much different from that of a well-structured problem; there is no explicit set of rules on how to solve such a problem, only an implied set of guidelines based on domain knowledge and experience (Ge & Land, 2003; Jonassen, 1997). According to Ge and Land (2003), representing the problem, justifying one's choices, monitoring the outcomes, and evaluating the solution are the major tasks required to solve an ill-structured problem. By first representing the problem, one can generate solutions by eliminating the causes of the problem and then develop methods for implementing the solutions (Ge & Land, 2003). The justification of one's choices is also important as the problem solver must select one final solution from many potential solutions, and must have solid reasoning when doing so (Ge & Land 2003; Jonassen, 1997). Monitoring and evaluation should be used throughout the process, from identifying the source of the problem to comparing one solution to the alternatives (Ge & Land, 2003; Jonassen 1997). Additionally, once a solution has been determined, it can be implemented and the cycle of receiving feedback and adapting the solution to that feedback can begin (Jonassen, 1997). It is important to note that the above tasks are not domain specific and provide merely a general outline of the ill-structured problem solving process.

We will now be looking at this problem solving process as it applies to ill-structured problems in the domain of human computer interaction (HCI). Consider a company who is in the process of updating their website to make it more user-friendly thereby increasing return on investment, a common goal in HCI. There are multiple ways to go about such a task and many correct solutions, which would qualify the task as an ill-structured problem. First, the team working on the website would want to represent their problem. In the domain of HCI this would mean exploring the problem space and generating profiles, personas, and scenarios of the target users. The team would also have to analyze the task to determine what functions the website should have to best fit their audience. Justification of choices would come into play during the next HCI step of formulating designs and prototypes. With each design for the possible solution, choices will be made on everything from features and font to layout and color. It is important that the HCI team can justify these choices. Once a final website design is agreed upon, it would go into development and then face deployment and evaluation. These last few steps fall under the ill-structured problem navigation steps of monitoring the outcomes and evaluating the solution. During the development process, certain functions and aspects of the website may be tested for user-friendliness and the outcomes would be monitored. Once the website is deployed, it would be evaluated on how well it accomplishes its intended goal. All throughout the process, the HCI team would monitor and evaluate their designs and choices, making necessary changes to ensure that their users have the best possible experience on their website.

As an HCI team, we would not want to violate the user experience. We therefore must take into account the individual knowledge representation. Generally speaking, an individual's knowledge representation is how he or she understands the world at a specific point in time. Following a constructionist view of knowledge, all new knowledge is built upon previous knowledge, which then changes the individual's knowledge representation. Therefore, ones' knowledge representation is based on previous experiences and exposure. In a team setting, each team member brings their own individual knowledge representation to the group. The extent that individuals share and discuss their respective knowledge representations directly impacts the success of the team (Cooke, 2000). The way relevant knowledge is represented amongst team members is known as the team knowledge representation (Mohammad, 2001). In order to aid team understanding of the knowledge representation, the knowledge can be represented visually. To display this knowledge representation visually, one can use a mindtool application (Jonassen 2000), such as a semantic networks and concept maps. The chosen mindtool application will serve as an interaction model, as well as conceptual model of how the users interact with the knowledge.

Interaction models that effectively support a user's ability to solve a problem require the conceptual model of the technology match the mental model of the user (Norman, 1987). In other words, the visual representation of the knowledge in the mindtool must closely match the individual's internal knowledge representation. Carrying this into a team structure, in order for a team to successfully navigate an ill-structured problem, the conceptual model of the mindtool application will have to match their team knowledge representation. Our research looks at how the feature of manipulation in interaction models affects the team knowledge representation. We believe that by having teams utilize a mindtool that allows manipulation; team members will communicate and share their knowledge with each other, creating a better team knowledge representation. Giving teams a visual display of a given way to construct knowledge provides the starting point to promote individual reflection about knowledge representation. Then, by offering the function of manipulation of the knowledge structure, teams must communicate directly about that structure therefore increasing the sharedness of the knowledge representation.

To get an accurate depiction of a group's shared knowledge representation, it is important to investigate communication in the group. Communication patterns in a group can provide us with information about how a group is functioning, how group members are relating with each other over time and how group members interact with each other (Tuckman & Jensen, 1977). Tuckman and Jensen (1977) reinvestigated the stages of "forming", "storming", "norming" and "performing" setting out to add another stage that incorporates "adjourning". Communication and behavior are different in each stage, but there has been known to be overlap (Tuckman & Jensen, 1977). A team's collective communication skills often correlate with the strength of individual member's ability to communicate, which also improve task interdependence (Yuan, Fulk, Monge, and Contractor, 2010). We will be using the Self Perceived Communication Competence scale (SPCC) by McCrosky (1985). The SPCC will give us an idea of interpersonal skills and an estimate of the perception of how the individual communicates in the group.

Discussions within groups improve utilization of member knowledge, though it is not always essential (Littlepage, Hollingshead, Drake & Littlepage, 2008). In groups that have lots of discussion, it helps with production and use of shared knowledge (Littlepage et al., 2008). We depend on others in groups for knowledge, and if two group members who are a part of a three-person group meet without the other person, they are often perceived as more competitive and consider themselves more competitive than those group members who engage the entire group especially in regards to negotiation (Palmer and Thompson, 1995).

Straus and McGrath (1994) found that impact of group satisfaction and success is directly related to how the group communicates. Those who interact face-to-face tended to be more successful than those who were communicating in a group trying to solve a problem over a computer media communication (Straus & McGrath, 1994). It seems to continue to hold true, as group members reported liking each other more in face-to-face interactions over a technological communication (Weisab & Atwater, 1999). Because we are trying to eliminate confounding variables, our groups will be tested in a face-to-face environment.

People often choose environments and situations where they feel confident they can experience a level of success, (Bandura,1989). Self-efficacy is the feeling of confidence in an individual's ability given a particular task (Bandura, 1989). An individual who has higher self-efficacy tends to visualize successful outcomes thereby raising the performance level and motivation (Bandura, 1989). Bandura (1989) argues that because we have a degree of certainty we judge for a task, we need to be able to measure efficacy accurately with relation to perception. However, we can expect that if they have a higher level of self-efficacy, we will see a higher level of performance of achieving goals (Bandura, 1989). Those who make very specific goals tend to have better performance (Brown and Latham, 2002). Those who were more committed to their goals also had higher self-efficacy (Brown and Latham, 2002).

Additionally, self-efficacy has a strong correlation to teamwork behavior and commitment to a team goal (Brown & Latham, 2002). Brown and Latham (2002) also indicate that individuals who perceived accomplishing tasks relative to their goal, that their enactive mastery would often correlate with higher self-efficacy scores. We interpret this as someone who has prior knowledge having more domain efficacy in relation to the task, whereas someone who is novice will not have a high score in domain self-efficacy. Bandura and Locke (2003) found that measuring group efficacy scores provides a basic measure that can correlate with other factors, like creativity, goal setting and commitment, and performance. Self-efficacy scores can provide insight to our predictions for measuring the group on a whole (Bandura & Locke, 2003). Brown and Latham (2002) also noted that higher goal commitment and efficacy scores often correlated with higher performance.

We can also look at self- efficacy in relation to group cohesion. Paskevich, Brawley, Dorsch and Widmeyer (1999) suggest group cohesion of task-related aspects had a strong correlation between collective efficacy in relation to the member's beliefs about one another. They found group member's shared belief of benefits and incentives exist and highly correlated with collective efficacy scores (Paskevich et. al, 2002). There is also evidence of higher performance within groups who scored higher on domain efficacy (Paskevich et. al, 2002). We can then deduct from the research that if our groups have high efficacy scores, that they may have higher goals and group cohesion (Paskevich et al, 2002).

In addition, it is important to investigate interaction models within groups. We are investigating interaction models which enhance a team's ability to navigate and solve ill-structured problems. An interaction model can be defined by breaking down the two components of the term. "Interactivity simplified to refer to a user who has access to a range of input devices which can activate the technology being used; the result of this action is some form of visual or audio output, and the sequence of actions form an interaction" (Sims, 1997). A model is an organize system. Another characteristic of interaction models that support users' abilities to solve ill-structured problems leave the user cognitively, socially, or emotionally in a different place.

We are focused on two interaction models, semantic nets and concept maps. Concept maps are a visual representation of a semantic network where each major term in the network is connected with a prepositional phrase. A concept map is a visual representation of a user's knowledge structure (Jonassen, 2000). Concept maps accelerate problem-solving performance and it helps learners to use the skill of searching for patterns and relationships (Jonassen, 2000). In Jonassen and Carr's, Mindtools: Affording Multiple Knowledge Representations for Learning, they describe many different mind-tools. The semantic networking mind-tool is where we discovered the semantic net interaction model. Semantic nets are concepts without prepositional phrases. According to Jonassen's study concept mapping improves important critical thinking skills, such as analyzing, evaluating, and connecting information, and also creative thinking skills such as expanding, extending, concretizing, analogizing, and visualizing ideas; complex thinking skills, particularly planning product (Jonassen, 2000). "One specific example we found was of a concept map with prepositional phrases that was used to show the connection between an interface model, interaction model, user model, domain model, application model, and task model. Their purpose was to help designers build online help for a computer application (Silveira, Barbosa, & Sieckenius, 2004).

Another relevant interaction model we found was used to construct a design structure for an online website for a woman's clothing line in India called *Ritu Kumar*. The Kumar model used semantic networking without prepositional phrases. This interaction model shows color coordination and overlapping subjects to categorize and to communicate the purchases online.

Keeping Jonassen's semantic networking theory in mind, the Kuman model and the Silveira, Barbosa, & Sieckenius interaction models have the possibility to enhance a team's' ability to navigate and solve ill-structured problem(s).

METHODS

We had two phases to our study. The first phase included usability testing of two design alternatives, and the second phase consisted of testing our final design alternative with teams of three to see how they leveraged the tool to solve an ill-structured problem.

Phase 1

During the first phase, we developed two interaction models using Justinmind wireframing software. The interaction models were based on different concept maps, but contained the same information within the domain of User Centered Design (UCD). In both concept maps, Color was used to signify the level of a node, with a total of four different levels. There was also a tree structure on the left side which showed the previous nodes selected and the path leading to the current location. Users could navigate through the concept map by clicking on any of the nodes, or by using the "Previous" and "More Design Models" buttons provided in the top left. Bottom level nodes contained a brief paragraph describing the given UCD method. Characteristics specific to the first concept map design included the use of overlapping nodes to connect ideas, and the ability to manipulate the nodes by changing the distance between them and changing the size of the nodes, see Figure 1. Such manipulation would allow the user to change the relationship between the nodes as well as the importance of specific nodes to make the concept map better represent the user's mental model. In contrast, the second concept map design used directional arrows with prepositional phrases, instead of overlapping nodes, to show a connection between the concepts, see Figure 2. Manipulation in the second concept map design consisted of the ability to add and remove the connecting arrows to better reflect the user's mental model.

In order to see which concept map was a better learning tool and determine any navigation issues, we conducted usability testing with four participants (n=4, 3M, 1F). Usability testing was conducted using UserZoom software, which allowed us to survey participants on their level of expertise in the area of UCD and their reaction to each of the concept maps. Each participant answered an initial survey of their experience in the domain and was then asked to navigate through nine tasks which used the first concept map. The participant was then asked to complete the same nine tasks, in a different order, using the second concept map. During the testing we gathered audio, mouse movements, click-throughs, and written responses to post-task questions. After the first two usability tests were completed, it was clear that the concept maps had navigation issues. To get the most out of our limited testing, we added a navigation map to the first concept map which provided a full view of all the nodes in the map as well as the user's current location and path. The last two usability tests were conducted on the updated concept map.

Analysis of the usability tests included the measurement of the user finding key components of information within the interaction model as well as mapping between the user's mental map in relation to the conceptual map of the model.

Phase 2

For the second part of our study, we used the results from our usability testing to create our final design alternative using Justinmind wireframing software, see Figure 3. The final concept map still used color to designate the four different levels and had a side structure to show the current path, but the buttons were removed so users' sole means of navigation was by clicking on the nodes. Directional arrows from the second concept map were used to connect the nodes, though they no longer had accompanying prepositional phrases. The decision to use directional arrows instead of overlap to show a relationship between nodes was based on feedback received during our usability testing, in which participants reported the arrows providing a level of structure and comfort. The navigation map from the updated version of the first concept map was also included, though it was now made clickable so users could jump to any part of the map easily. We also added richer media to the bottom level nodes including images, examples, and webpages to give users a better understanding of the given UCD concept and make the information more digestible. Due to time and software constraints, the final model contained no means of manipulation so any changes to the model had to be drawn out on scrap paper.

The final design alternative was tested with teams of three members (n=4 teams) in a range of teams who never worked together before and teams who have formed in the past six months. Each team participated in a two hour session with the following structure: First 10 minutes complete an individual questionnaire which measured problem solving abilities, domain self-efficacy, individual knowledge representation, and team communication skills, 20 minutes to individually draw a concept map using a list of User Centered Design terms identical to those in the final design alternative, 1 hour to use the interaction model to solve an ill-structured problem as a team, 20 minutes to individually redraw or make changes to their original concept map, and the last 10 minutes to complete a questionnaire identical to the one at the beginning. The testing environment consisted of a single room with chairs, a table, scrap paper with markers, and two computers. One computer ran the interaction model while the second computer ran a Skype session which allowed the team to ask questions and receive additional information about the problem they were trying to solve. Two of the four teams were given the option to use scrap paper to manipulate the concept map to make it a closer match to their team knowledge representation. During the testing, we gathered audio, video, mouse movements, click-throughs, dialog from the Skype session, as well as any notes the team made on scrap paper.

All the teams were asked to solve the following ill-structured problem:

> *"You are a user experience expert and a local client, Mary, has requested your services. The following initial problem statement is what you*

currently understand about the work you will be taking on with Mary.

Mary is a professional dog handler. Mary's clients want their dogs to be show dogs, but they don't have the time to travel all over the country to earn titles. Mary's main responsibilities include traveling with the dogs and presenting them at shows. Mary handles 5 to 15 dogs at any given time. Mary is on the road a lot and trying to use on-the-road computing can be a challenge with limited Internet availability in many locations.

Mary needs a system to help her schedule the right shows for each dog, ensure veterinarian care, set up a grooming schedule for the dogs, manage feeding schedules among all the dogs, and get reminders about ring show times. Mary also needs a system to help her keep track of billing to ensure she gets paid for her work, manage her busy schedule between shows and client appointments, and a way to keep in touch with the dog owners.

Ultimately, Mary would like something to help her organize her schedule, business, and billing that would save her time."

The problem was delivered via a handout in the first experiment and via a Skype message in the last three experiments.

By navigating through the interaction model, teams could learn about the different steps and methods of UCD. The team could then request, via Skype, to perform one of the methods to gain more information on Mary's problem. Information and answers to these possible requests had been accumulated and organized prior to testing.

After testing the first team, we decided to make some changes to our testing procedure so it will be necessary to view each team testing session as a separate experiment. The main change in the procedure was the amount of structure given to the team to guide them in their navigation of the problem. The first team had no structure, they used neither the interaction model we had provided nor the Skype session to learn more about Mary, and instead they focused on developing an end product. The second team had a small amount of structure, in which they were asked them to explore the interaction model for 10 minutes and then work on solving the actual problem for 50 minutes. While the second team did explore, they still focused more on developing an end product than implementing UCD methods. The third and fourth teams had a larger amount of structure, in which they were asked to explore the interaction model for 10 minutes, use the interaction model to develop a plan for solving the problem and identify concepts they would use for 10-20 minutes, and then apply their plan to solve the problem for the remaining 40 minutes. Teams who had the larger amount of structure generated more ideas before focusing on the final solution. Additional testing is needed to further refine the testing procedure so that teams are encouraged to use and have a clear understanding of the tools they are given to solve the ill-structured problem.

Analysis of the team testing included the before and after questionnaire and concept map for each team member, the number of times a team made an assumption about the given problem, the amount of time spent on brainstorming ideas, the amount of time spent developing an end product, and the number of times the team referenced a UCD method in the interaction model. We also did word counts for certain phrases used by each team during their session. To determine how successful a team was in their final solution, we compared the team solution to an expert solution, which was based on feedback from individuals who have significant experience in the field of User Centered Design.

OBSERVATIONS AND RESULTS

Overall, we noticed several trends based on concept maps. We will be discussing common themes among group members in relation to average node connection or how many times terms were on the concept map. We will also discuss any similar structural patterns among group member concept maps in relation to the team. Sometimes after a discussion or exposure of a term, we may also see that having an impact on the second concept map. Common themes of terms in both the before and after testing have been averaged out and represent an overall knowledge representation on user centered design.

The first team each used the terms and put a high emphasis on design (average node connection of 6) and usability testing (average node connection of 6), see Figure 4. They each used and had a medium emphasis on develop prototype (average node connection of 3), planning (average node connection of 5) and early prototype (average node connection of 4). Overall, appearance was very similar with the use of nodes and directional arrows. The group members would make connections of several nodes to one node, and often the connection of other terms would be linked once.

This team also had 5 points of converging, and 4 times of diverging in an hour long session. They made 8 blind assumptions, and 16 educated assumptions in the hour as well. In relation to process problem solving, there were 4 marked times. This team said "she needs" the most, being 47 times, which were included in the assumption numbers. They also used assumptive language of "I think" 29 times.

The second team, on the other hand, each used and had high emphasis on design (average node connection of 7).They each used and had a medium emphasis on Determine feasibility (average node connection of 3), develop costs (average node connection of 2), learn about users (average node connection of 3), and understanding needs (average node connection of 3). This group was also resistant to making new concept maps, and had overall structure of no nodes, terms connected by lines or overlapping nodes with lots of terms in them.

This team had 7 points of converging, 5 points of diverging in their hour long session. They had made 7 blind assumptions and 10 educated assumptions. They had a 2 marked solving problem process times. This team said “she needs” 18 times, “I know” 2 times and “I think” 9 times in an hour long session.

In contrast, the third team had no major emphasis on terms but all used develop prototype (average node connection of 5), UCD design (average connection of 3), Develop costs (average node connection of 2), prototype (average node connection of 2), usability testing (average node connection of 4) and surveys (average node connection of 3). There was no major resistance to a second map, and they all used nodes in connection to hubs with directional arrows and lines.

This team had 2 points of convergence, 11 points of divergence and 10 marked times related to problem solving process. They made 1 blind assumption and 4 educated assumptions in a one hour period. This team said “she needs” 24 times, “I know” 2 times and “I think” 11 times in an hour long session.

Lastly, the fourth team had all used terms with high connections that include concept phase (average node connection of 7), design (average node connection of 6), and usability testing (average node connection of 4). They each used and had medium emphasis on high level design (average node connection of 3), early prototype (average node connection of 3), and develop prototype (average node connection of 2). They each had very linear nodes with connections that had levels indicating a step in a list-like structure.

Our last team had 8 points of convergence, 10 points of divergence and 14 marked points related to problem solving process. They made 1 blind assumption and 10 educated assumptions in a one hour period. This team said “she needs” 22 times, “I know” 2 times and “I think” 10 times in an hour long session.

CONCLUSION

We may be able to determine from this data that the more structure and direction a team is given, the more they will use the tool and the less assumptive language will be used to solve a problem around user centered design. The team who had the most time for the problem-solving session, were not given any structure and appeared to not use the delivery system as much, had the most blind and educated assumptions. It appears teams made less blind assumptions and more educated assumptions when there was more structure introduced in the problem solving session. The same might be true for assumptive language used; the team who were given structure through the session mentions the most nodes for their process of solving the problem. Teams who were given the large amount of structure spent more time brainstorming and exploring possibilities (Diverge) compared to teams who were given no or small amounts of structure. Teams who had less time had more divergences, though it is more likely that this is due to the structure, as mentioned previously.

There are some interesting thoughts about the concept map we did not get to further explore. Gerstner and Bogner (2009) had looked at learning ability and concept map structure in younger children, and they found that the map structure was related to the teaching style, but not learning the concepts overall. We feel there should be future emphasis on interpretation of the concept map to attempt to understand a background of the individual in relation to team knowledge representation. We feel that the team’s ability to learn may be affected by the structure of the map overall, and a possible link between interaction with a concept map and future beliefs of how terms are related to one another.

Teams that interacted and collaborated more also seemed to have very similar terms and structures on their concept maps. It may be beneficial to further investigate the ability of team’s communication patters in relation to the knowledge representation. The teams that collaborated more about the information tended to use very similar terms in their second representation. Groups that had very high resistance to the change submitted in their models also appeared to use the model less.

The teams that had the most assumptions including blind and educated, appeared to be further from expert solution compared to the teams that had less amounts of assumptions combined. Another interesting phenomenon about the assumptions is the overall communication patterns used. Those who were higher in assumptions also had more aggressive communication patters, for instance not letting a group member finish speaking, talking louder over other group members, and repeating words or phrases previously stated. Groups who were lower in assumptions had communication patterns of letting group members finish speaking, speaking at an adequate pitch and having more supportive affirmations, for instance saying yes, that’s good or having head nods.

The teams that used more of the information delivery system on the client via Skype also tended to make less assumptive comments. The Skype session was to simulate interactions to learn more about the client. A future study may want to utilize an actor with a script, a video of an actual person, or some other simulation of interaction to have it appear more realistic to participants. A common complaint was usually that they were not aware that was a way to interact with the pretend client, and many thought the use of computer via Skype was not very convincing. This may be in relation to the Straus and McGrath (1994) study where teams that interact with each other face to face performed better than those that did not. This may be true in relation when trying to consider a client interacting to attempt to get a product out. Thought the client may not be an official member of the team, they are still an important part of the problem solving process of user centered design.

Something that may be useful to further investigate would be scaffolding learning verses non scaffolding learning environments. A suggestion for those looking at these types of studies would be along the lines of time use to learning the problem and the amount of consulting an outside source. Though we were trying to simulate a real world environment with minimal scaffolding, it appears groups that had more instruction tended to do better with task on hand than those groups who had little to no structure or guidance with how to use the equipment provided.

We also would advise future research to focus on the use of scaffolding in a new learning environment. Based off team performance and solution, we have several unanswered questions related to the amount of scaffolding provided to teams. It appeared that teams that had more structure and direction did slightly better. However, there were several unexplored factors that could also relate to a team's ability to have shared knowledge representation, problem solving abilities and communication skills. We would encourage further studies looking at these individual variables more closely to investigate any significant correlation.

Overall, we hope our pilot study will provide future insight to those investigating the problem solving process within the team. Therefore, we have several recommendations for future studies. One example may include extending this study to a more longitudinal design. If our testing was more spaced out, it may have yielded different results on our individual testing in relation to team work. We had several analyses we were unable incorporate due to time constraints. Because this was a pilot study with the full intent to possibly gain some insight, we hope to utilize several things for future studies. Future studies may want to incorporate the ability of a team to accurately depict information for them using the terms. One example of this may be the use of a low fidelity design made by the teams with sticky notes and yarn. If our model presented was easier to manipulate and saved manipulations, we would encourage use of that. Our model was not easy to manipulate and therefore, we do not suggest a confined computer-bound method for future studies if attempting to measure manipulation.

ACKNOWLEDGEMENTS

We would like to acknowledge Andrea Peer (MS) who served as our Graduate Student Mentor on this project, as well as Sree Nilakanta (PhD), our Faculty Mentor. Their encouragement and guidance contributed greatly to our project.

This research was performed at Iowa State University as part of the SPIRE-EIT research internship sponsored by the Human Computer Interaction Program during the summer of 2011.

This material is based upon work supported by the National Science Foundation under Grant No. IIS-0851976. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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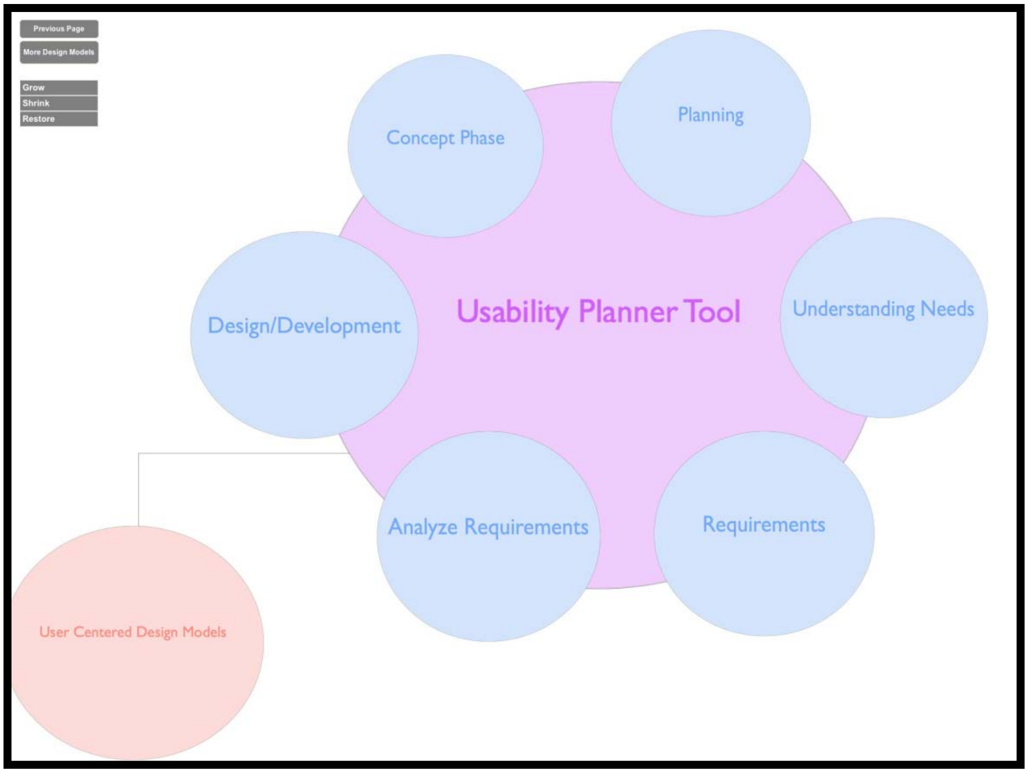

Figure 1 Our first concept map.

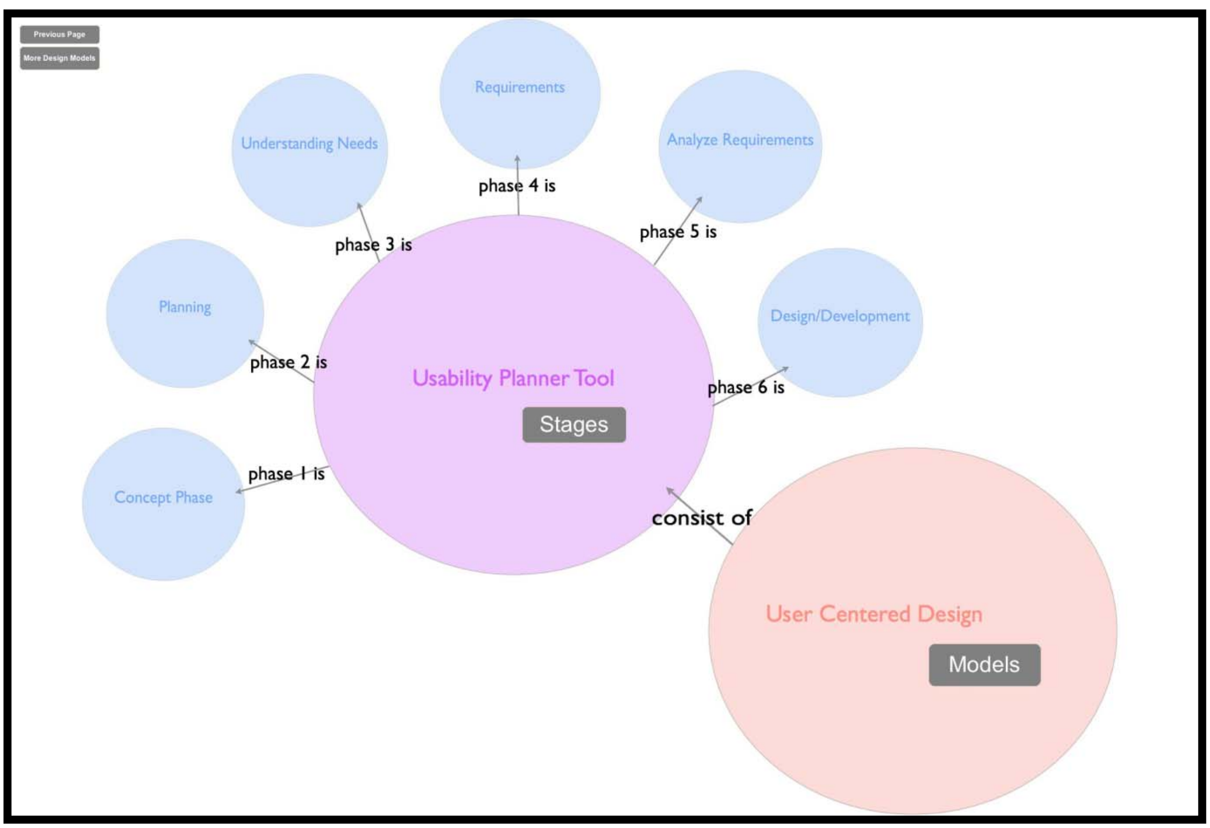

Figure 2 Our second concept map.

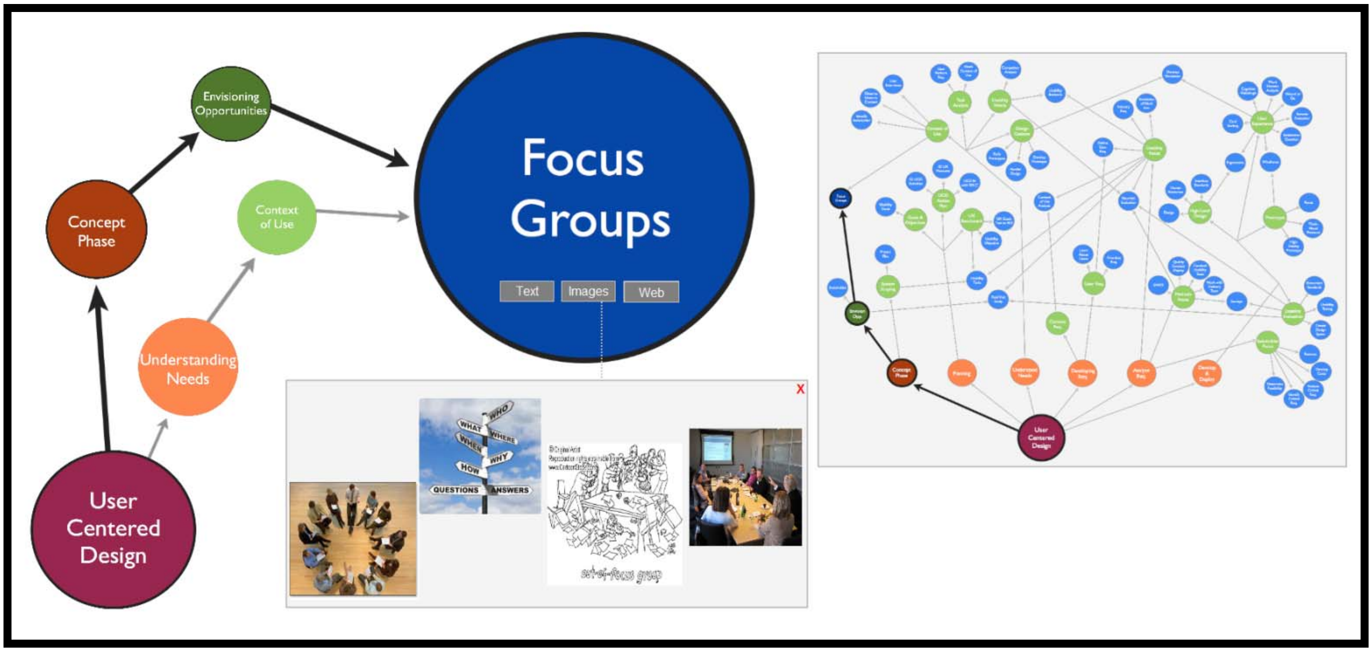

Figure 3 Our third and final concept map.

Team 1	**Node Name**	Design	Usability Testing	Develop Prototype	Early Prototype	Planning	
	Average Node Connections	6	6	3	4	5	
Team 2	**Node Name**	Design	Determine Feasibility	Develop Costs	Learn about Users	Understanding Needs	
	Average Node Connections	7	3	2	3	3	
Team 3	**Node Name**	Develop Prototype	UCD Design	Develop Costs	Prototype	Usability Testing	Surveys
	Average Node Connections	5	3	2	2	4	3
Team 4	**Node Name**	Design	Usability Testing	Develop Prototype	Early Prototype	High Level Design	Concept Phase
	Average Node Connections	6	4	2	3	3	7

Figure 4 Average connections in individual concept maps.

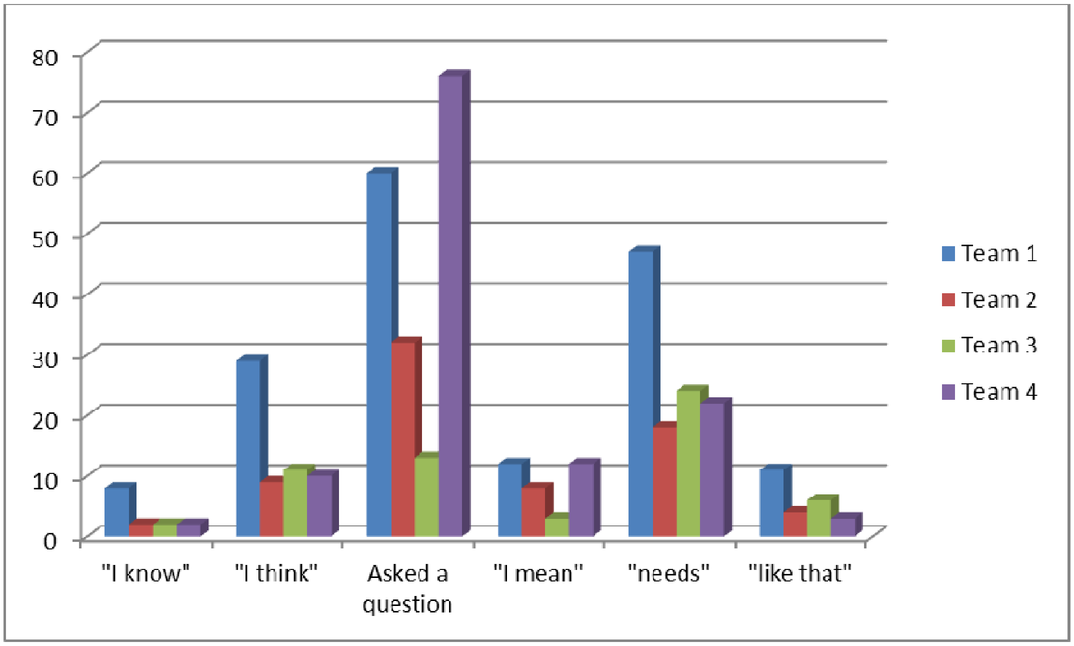

Figure 5 Word count for each team.