Analysis of the Impact of User Interaction on Prototyping Productivity during Product Development

by

Hallie Sue Cho

SUBMITTED TO THE DEPARTMENT OF MECHANICAL ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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AT THE

MASSACHUETTS INSTITUTE OF TECHNOLOGY

JUNE 2010

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ABSTRACT

User involvement has been widely supported by both researchers and management as a critical factor in new product design (Cooper and Kleinshmidt, 1990; Foxall and Johnston 1987; Kanter, 1988; Parkinson, 1982; Rothwell et al., 1974; von Hippel, 1988). However, because of the time consuming and costly nature of user involvement, there has been studies that try to show at what stage of product development user involvement is critical or has the most influence on performance. By examining time sheet data reported by professional student teams from a graduate level product design course, we found that emphasis on user involvement during the early stages of development actually has no correlation to the total amount of time a team had spent during their product development process. We also found that brainstorming promotes teams to spend more time during prototyping stages and that when teams are constrained in time, they spend less on prototyping and put more emphasis on user interaction.

Thesis Supervisor: Maria C. Yang
Title: Robert N. Noyce Assistant Professor of Mechanical Engineering and Engineering Systems

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I would like to thank Professor Maria Yang for all the guidance, insight, and support; Justin for answering all of my questions and being very helpful throughout the process; Jesse, Geoff, and the ideation lab for creating a friendly work environment and helping me focus. And finally, I would like to thank Mom, Dad, and Grace for all the support and my friends for the never-ending encouragements!

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1. INTRODUCTION

New product development is undoubtedly of critical importance to most firms because new products are what give a firm its competitive edge and determines its success in the long run. With countless number of products in different industries, the literature on product development is vast and often has conflicting views on how the product development process should be designed.

Involvement of users in the product development process has been widely supported as a critical factor that influences new product success by both researchers and management (Cooper and Kleinshmidt, 1990; Foxall and Johnston 1987; Kanter, 1988; Parkinson, 1982; Rothwell et al., 1974; von Hippel, 1976, 1977a, 1977b, 1981, 1988). Some have firmly asserted that building in the voice of the customer has become a critical success factor in new product development (Cooper, 1999), while others are skeptical to embrace this key ingredient to product success because user interactions can be very costly in terms of time and resources (Schrader and Gopfert, 1998). There also have been studies that report disappointing results from user involvement in new product developments (Clegg et al, 1996; Campbell and Cooper, 1999).

Much of literature on new product development concludes that user involvement during development is helpful in developing a successful product. However, because user involvement can be costly and conflicts arising from involving more people in the team can be burdensome for the developers, "the more the better" approach to user involvement (Kanter 1988) needs further examination. Although it is difficult to determine exact cause of success of a

product given multitude of variables, project teams and management may be interested in learning how user involvement in different stages of new product development can affect the development process as a whole.

This study attempts to better understand the relationship between different stages of product development by studying how different development teams manage their time given the same resources and guidelines. The next section will explore in detail relationships between user interaction and new product development found in literature. The method section shows how appropriate data was collected and then analyzed. After results and conclusion, future research suggestions and applications to management are discussed.

2. Literature Review

2.1 Importance of user interaction

Studying a product's potential target market and incorporating this market intelligence into development process has been recognized as an important antecedent to new product performance both in marketing and new product development literature (Kahn, 2001). Most successful products on the market today are successful because they serve a real customer need and create value for consumers. The presence of a genuine need has been identified as an essential cause of success or failure (Lai et al, 2009). Studies by Allen (1977, 1986) also suggest that extensive user involvement are useful for generating critical ideas and inputs and generally lead to improved product performance. This

needfinding has been defined as a qualitative research approach to studying people to identify their unmet needs in order to help designers get closer to their end users (McKim, 1972).

Identifying potential customers and understanding market characteristics are critical because it allows a firm to explore innovation opportunities created by emerging market demand as well as to reduce potential risks of being a misfit to user needs (Li and Calatone, 1998). User involvement reduces potential risks of not accurately addressing the core user needs by getting rid of the uncertainty. By interacting with the potential users, developers get a more accurate sense of whom they are designing for and what their needs are; hence, they are better equipped to determine a more precise list of user requirements (Ives and Olsen, 1984). Garcia-Murillo and Annabi (2002) have also shown that direct interactions with users allow developers to gain rich content and help explain customer behavior, which development teams can start addressing early on in new product development.

Without any user interaction during the development stages, development teams will gain user knowledge after the product has launched and they start receiving user feedback. At this point, firms have the option of listening to their customers and re-developing the product to release an update or keeping the less than optimal product on the market. Both cases render the product development process inefficient and costly in terms of cost of new development or forgone revenue due to less than expected performance. Foxall and Johnston (19987) have shown that user involvement during product development reduces research and development costs for the firm by decreasing

or eliminating the need to generate and evaluate ideas or concepts. Cost to the development team is reduced since users are now doing the needfinding and brainstorming instead of development teams. This paper will attempt to verify this statement by examining the relationship between time spent with user testing and time spent on concept generation and selection during new product development.

Much of the literature on new product development supports that a steady stream of user information is most useful and that more user involvement is better for both the developers and users in the long term since users will benefit from a product that serves their need and the developers will have developed a successful product. Kanter (1988) concludes that extensive interactions with a few potential users as well as not as extensive interactions with numerous potential users are both helpful for the development team. This study supports that to produce innovation, expansive complexity created by more relationships, more sources of information, more angles on the problem, and more ways to pull in human and material resources are essential because this attempts to lessen the uncertainty and risk of failure that is inherent in the nature of innovation.

2.2 Cost effectiveness of user interaction

Although user involvement is generally thought of as having a positive influence on a product's success, user involvement can be very costly. Therefore, even though studies have shown that consistent user interaction throughout all

of the new product development stages can enhance the effectiveness of user involvement, in terms of cost efficiency, this may not be an effective way of incorporating user interaction into product development. Development teams and firms may benefit from knowing user involvement in which stages of development can offer most valuable feedbacks.

User involvement can be very costly for a new product development team because it is difficult to identify potential users for a product that does not exist yet, compensating for users' time is costly, and opportunity cost of spending time with the users to educate them about the product and gain feedback can be costly for the team depending on the quality of feedback. User involvement can also hinder product development by creating conflicts regarding user selection, determining the timing and intensity of user involvement, user's ability and willingness to provide right knowledge, and the nature and extent of that knowledge (Campbell and Cooper, 1999). Other risks of user involvement are negative product publicity due to premature test result dissemination and inaccurate product performance data generation or unrepresentative feedbacks (Dolan and Matthews, 1993).

Given the drawbacks of user involvement, firms and development teams are faced with two different views regarding during what stage of the development they should place emphasis on user interaction. Lai, Honda, and Yang (2009) found that at the start of a product development process user interaction generally tends to focus on needfinding and defining requirements, but at the end of the process the emphasis shifts to user testing and concept evaluation. Same study also shows that there is a significant negative correlation

between user interaction and flexibility in decision-making during concept selection stage, which reflects additional strain placed on the team by user feedback. Additionally, in the later stages of development, user interaction and commitment to the project at hand has been shown to have a strong positive correlation (Lai et al, 2009)—indicating that users are actually a distraction when it comes to deciding on a product concept but that they are helpful in concept refinement and giving feedback on prototypes. Rochford and Rudelius (1997) on the other hand present that the insight and information gained from the users in the early stages of product development can be helpful in resolving problems regarding market uncertainty, which may reduce costs and problems in the later stages of development; this is the case of developers who have done extensive market research and produce a successful product on the first iteration of the development cycle with less of a need for user testing and further improvements. This study will analyze the relationships between time spent in different segments of development process to examine the existence of a relationship between time spent with user involvement and time spent during other product development segments.

2.3 Other factors

In a study conducted within a product design class, projects with the highest rating for desirability and an understanding of how they fit in with their competitors tend to have high scores for other questions as well, which suggests that these two aspects of a product were leading indicators for reviewers when

rating a product's assessment (Lai et al, 2009). Teams who had a good understanding of how they fit in with their competitors are likely to have spent a significant amount of time conducting market research as well as understanding customer needs as to position themselves well.

The study also observed that many of the correlations between user interactions and reviewer scores in different categories were negative which would suggest that more interactions with users tend to correlate with poorer ratings. This finding raises questions and calls for a further study of user involvement's place in new product development. Both teams with high and low overall reviewer rankings spent time with users; hence, user interaction alone was not a predictor of success. However, there was a significant positive correlation between amount of time spent prototyping and high reviewer ratings (Lai et al, 2009). This paper will also take a closer look at time spent with prototyping and examine if there are any other relationships with other stages of product development.

3. RESEARCH METHODS

Time sheet data was collected from a product development class at MIT. Teams were made up of professionals in the same industry. Each team was given the same budget and same guidelines as to how new product development can be designed. At the end of each milestone for the class, individual team members were asked to fill out a time sheet (see APPENDIX A), which asked how much was time spent in each of the following development processes. User market

research: investigating or identifying markets, customers, or users through interviews and other techniques (includes users testing); concept generation: formulating design solutions (i.e. brainstorming); concept selection: evaluating and choosing concepts (includes product testing); design: planning the details of concepts and how they will function and look; building: fabricating or coding a concept (includes prototyping and working with vendors); business plan: planning future development and financial projections. The business plan section was determined to play a significant role for only the final presentation milestone and was subsequently removed from the analysis of this study.

All of the time sheet data were gathered through an online form and was exported to excel files. Out of 18 teams, 9 teams were randomly chosen and their individual time sheet data for user market research, concept generation, concept selection, design, and building were considered. User market research was more broadly labeled as "User Interaction" as it included both studying market characteristics and direct user involvement. Concept generation and selection were combined and labeled as "Brainstorming." And, design and building was combined and labeled as "Prototyping."

Time sheet data from individuals were combined to form team hours. Team hours for user interaction, brainstorming, and prototyping for each of the milestones as well as total hours spent during product development was examined.

4. RESULTS

Pearson product-moment correlations were used for all of the following data sets to determine the strength of dependence.

4.1 Relationship between different stages in terms of actual hours reported

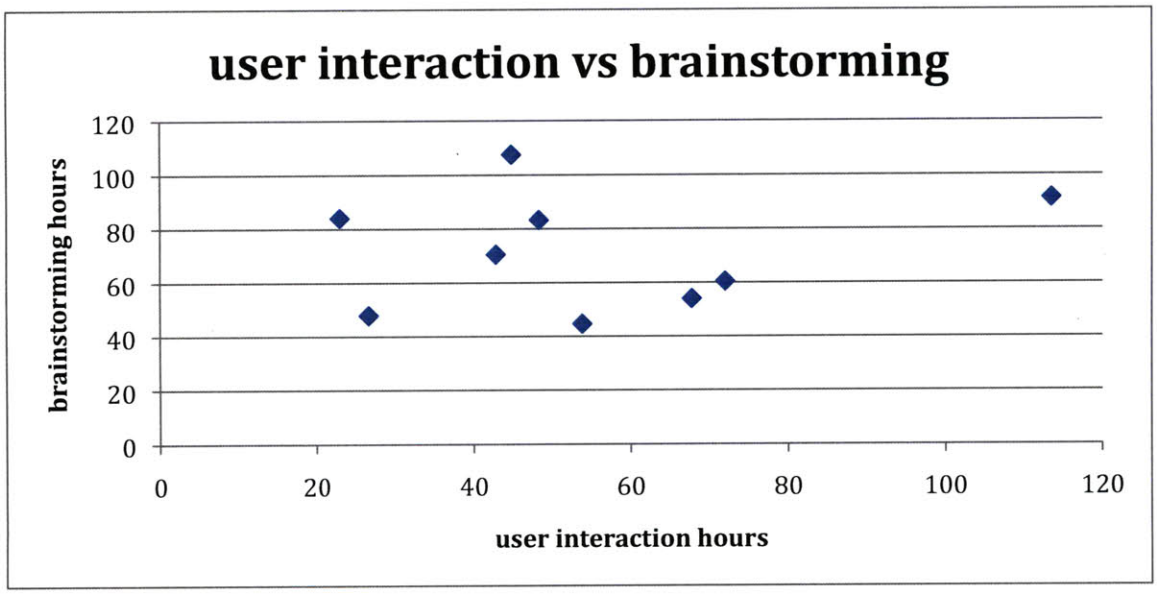

Figure 1: Scatter plot of user interaction hours against brainstorming hours. Correlation of time spent between the two stages of development is low: 0.1313.

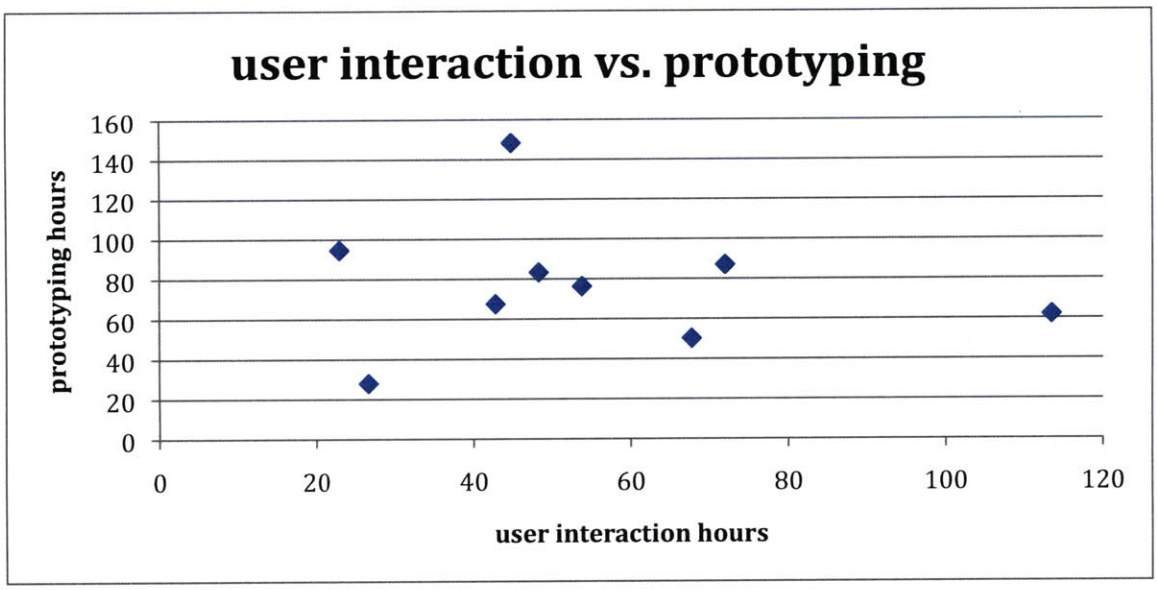

Figure 2: Scatter plot of user interaction hours against prototyping hours. Correlation of time spent between the two stages of development is low: -0.1182.

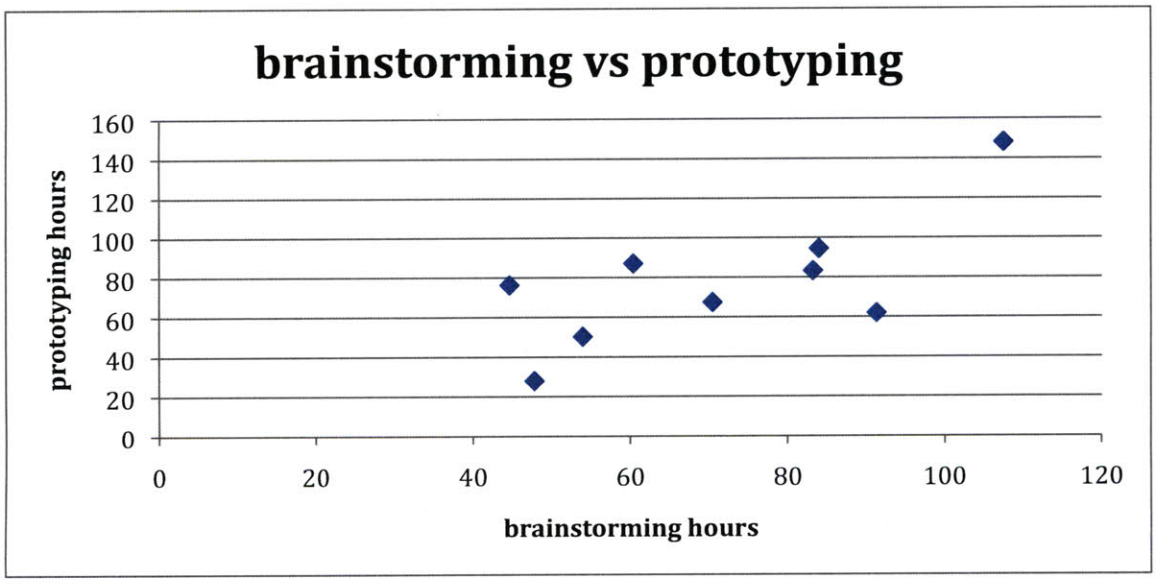

Figure 3: Scatter plot of brainstorming hours against prototyping hours. Correlation of time spent between the two stages of development is high: 0.7141.

Figures 1 through 3 uses actual hours reported by each of the 9 teams analyzed (see APPENDIX B to view break down of individual team's reported hours per milestone). Time spent in user interaction and time spent in

brainstorming has a correlation of 0.1313 (see Figure 1), which suggests that there is no apparent relationship between how much time a team spends with users and how much time they spend on concept generation and selection. Time spent in user interaction and time spent in prototyping has a correlation of -0.1182 (see Figure 2). The low value of the correlation shows that there is no significant relationship between the two stages of development. However, the negative correlation value suggests that more time spent with users is correlated to spending less time prototyping. Time spent on brainstorming and time spent on prototyping has a correlation of 0.7141 (see Figure 3). The high positive correlation value suggests that there is a significant positive relationship between brainstorming and prototyping.

4.2 Relationship between different stages in terms of percent of total hours

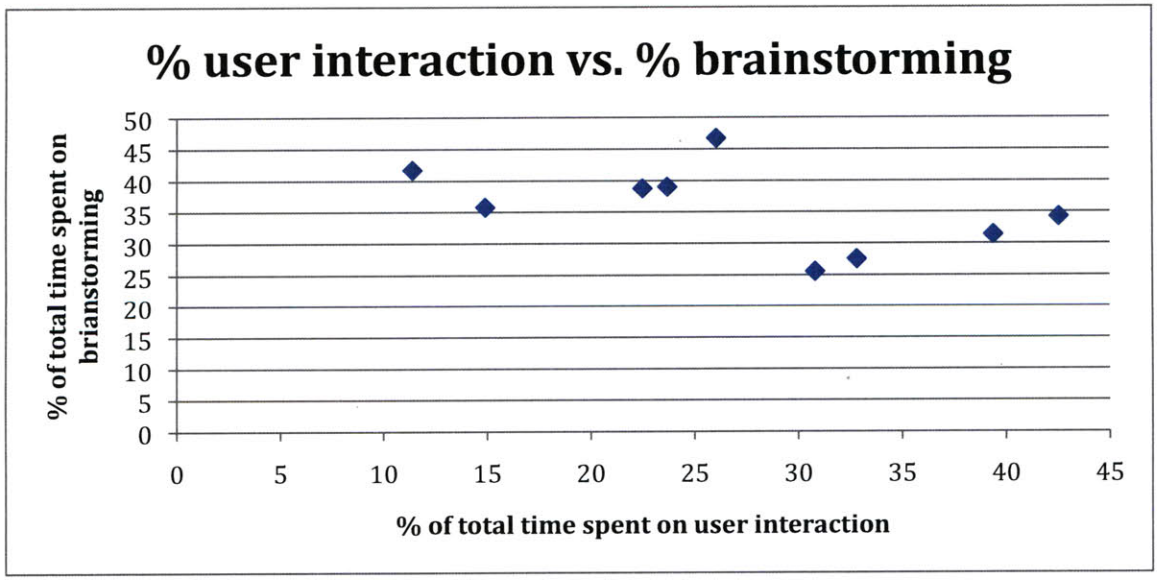

Figure 4: Scatter plot of user interaction as a percentage of total design hours against brainstorming as a percentage of total design hours. Correlation of time spent between the two stages of development is -0.5174.

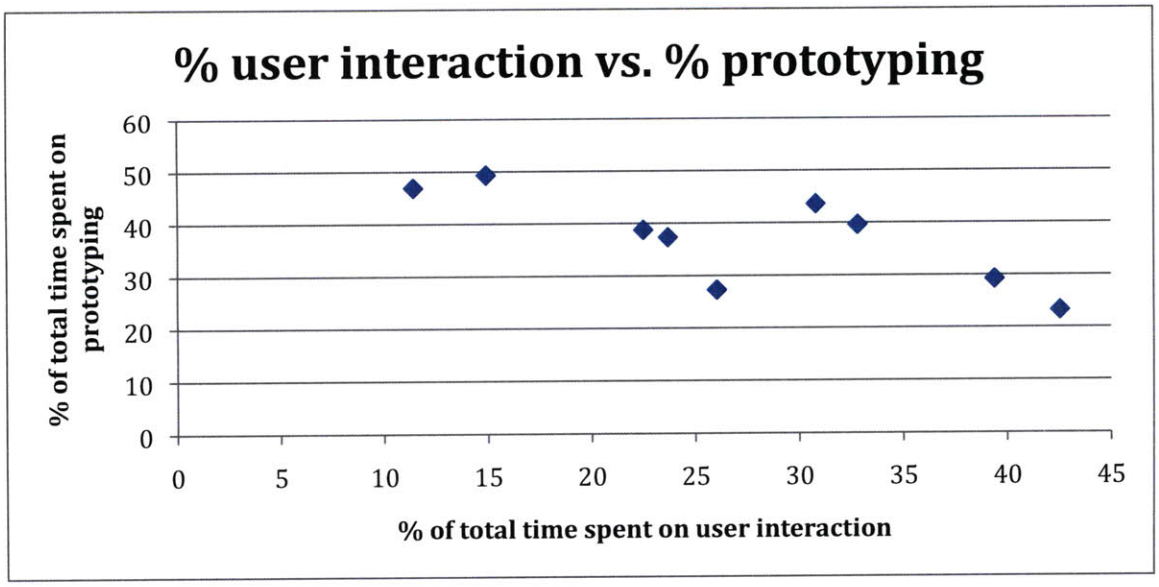

Figure 5: Scatter plot of user interaction as a percentage of total design hours against prototyping as a percentage of total design hours. Correlation of time spent between the two stages of development is -0.7651.

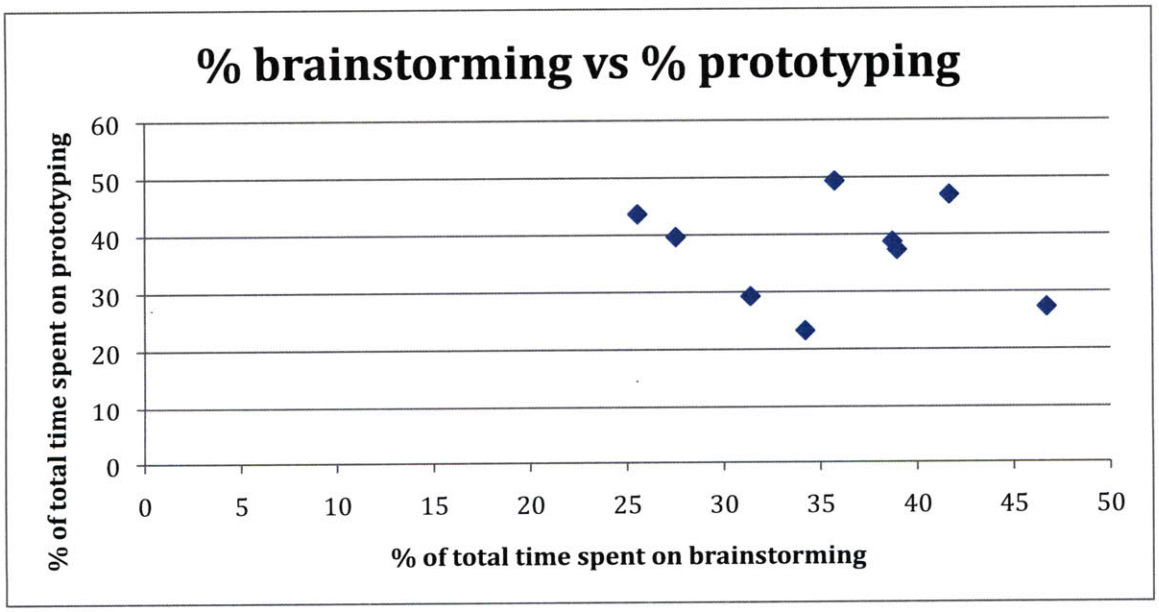

Figure 6: Scatter plot of brainstorming as a percentage of total design hours against prototyping as a percentage of total design hours. Correlation of time spent between the two stages of development is -0.1551.

Figures 4 through 6 uses the timesheet information as a percentage of the total time spent during each team's development process. It is important to note that total time here is the sum of hours spent on user interaction, brainstorming, and prototyping as defined by this study and not a cumulative of the times spent by each team for the product design class. The negative correlations are caused by taking the percentage of total time spent. This analysis does not take into account how the teams will behave given more time; it assumes that the total hours spent by a team is the number of hours available to them. Hence, an increase of time spent in one segment would lead to a decrease of time spent in the other segments. For the purpose of this study, the absolute value of the correlations will be considered.

Comparing the timesheet data as a percentage of total time spent reveals different finding from analysis of actual hours spent. The reason for examining the time spent in a segment as a percentage of the total time spent by a team is that teams devoted various amounts of time, and it may have been interesting to compare what percent of each team's development process was dedicated to different development segments. This analysis reveals that there is a relatively strong correlation of 0.7651 (see Figure 5) between user interaction stages and prototyping stages; a weaker correlation of 0.5714 (see Figure 4) between user interaction stages and brainstorming stages; and a relatively insignificant 0.1551 (see Figure 6) between brainstorming stages and prototyping stages, which directly contradicts finding discussed in section 4.1.

4.3 Relationship between number of hours spent in user interaction and number of hours spent total during development.

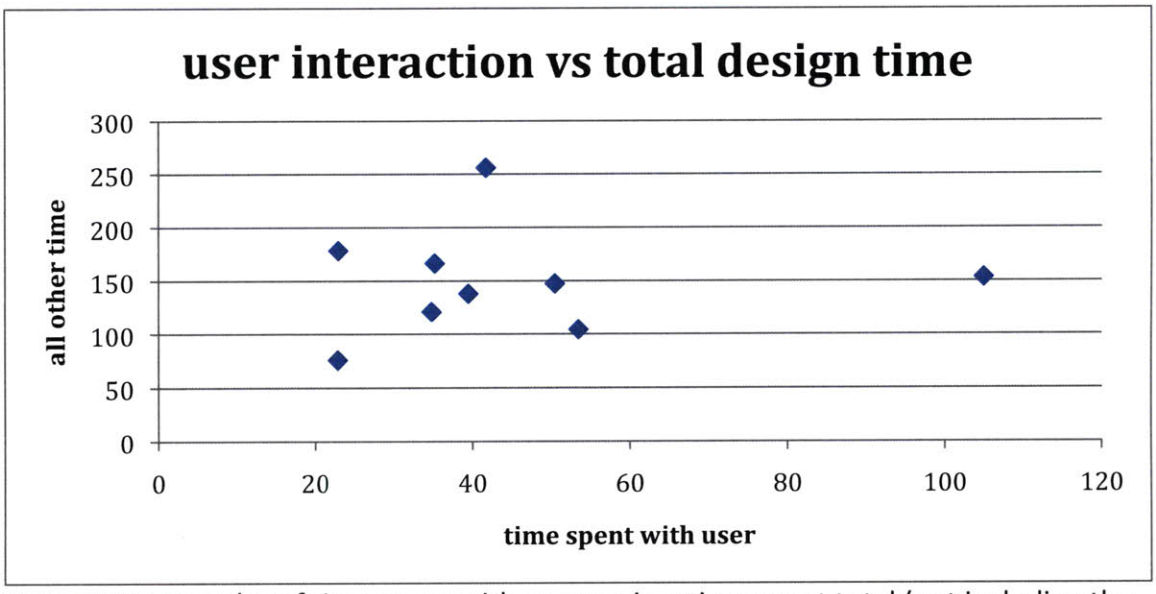

Figure 7: Scatter plot of time spent with user against time spent total (not including the user interaction time. Correlation of time spent between user interaction and total design time is 0.0659.

There was no apparent relationship between how much time a team spent with user interaction and how much time the team ended up spending overall.

5. DISCUSSION

A product's success can be attributed to its inherent value, effective marketing, sales efforts, efficient management of business, and many other factors. The literature review on new product development has shown that to answer customer needs and design a value-creating product, user involvement in every stage of development is recommended. Furthermore, user involvement

in the early stages of development has been identified as having most influence. As stated previously in the literature review, Rudelius (1997) showed that the insight and information gained from the users in the early stages of product development can be helpful in resolving problems regarding market uncertainty, which may reduce costs and problems in the later stages of development. However, upon analysis of time spent with user interaction in the early stages of development and total time spent in product development (see Figure 7), there has not been a significant correlation, and it is difficult to conclude that Rudelius's statement is true.

Additionally, Foxall and Johnston (1987) have shown that user involvement during product development reduces research and development costs for the firm by decreasing or eliminating the need to generate and evaluate ideas or concepts. However, Figure 1 shows that there is a very weak correlation between time spent in user interaction and time spent in brainstorming, which included concept generation and selection. Also important to note is that however weak, the correlation is positive—indicating that user interaction promotes further brainstorming, which directly contradicts Foxall and Johnston's statement.

An interesting finding is the unexpected strong positive correlation between time spent in brainstorming and time spent in prototyping. The positive correlation can be explained by the fact that when development teams spent time generating ideas and selecting which concepts to continue, they are likely to make initial sketch models and more refined conceptual models to test feasibility

of the developed ideas and therefore end up spending more time prototyping than the teams that did not spend as much time brainstorming.

Instead of observing relationships between absolute hours spent, examining what percentage of total time spent during development process was devoted to each of the segments, user interaction, brainstorming, and prototyping, revealed different results from the previously mentioned absolute hours. Unlike the dataset with absolute hours, which revealed that brainstorming and prototyping had a strong relationship, the comparison of percentages showed that brainstorming and prototyping had a weak relationship and that user interaction and prototyping had a strong relationship (see Figures 4-6).

6. CONCLUSION

This study examined relationships among time spent during user interaction, brainstorming, and prototyping stages of new product development process and found that: 1) there is no significant relationship between time spent with user interaction in the early stages of development and total time spent during the development to support the claim that user interaction reduces research and development costs; 2) there is no significant relationship between time spent with user interaction and time spent with brainstorming to support the claim that user interaction reduces or eliminates time spent on concept generation and selection; 3) the strong positive relationship between time spent with brainstorming and prototyping shows that teams who spend more time on brainstorming tend to also spend more time on prototyping; 4) the strong

negative relationship between percent of total time spent on user interaction and percentage of total time spent on prototyping shows that given a time constraint, teams prefer to spend more of their time with user interaction than prototyping, which also suggests that when a team is constrained in resources, they tend to value user knowledge more than what they learn by iterative prototyping.

Because new products developed by the teams never went to market, there is no way to determine what were the factors within development that contributed to success. The next steps for this study would be to examine reviewer ratings and feedbacks and study the relationship between positive feedback for categories such as desirability and usability and time spent on development stages. Another concept to further explore is the comparison between teams who have steady stream of user involvement throughout the process, teams who "get it right the first time around" and spend many hours with users in the early stages but do not have any user interaction in the later stages, and teams who do the needfinding on their own and spend no time with users in the early stages but extensive use user involvement in the later stages of testing. It would also be interesting to delve deeper into the reported timesheet data and determine how much time was reported with what type of user interaction and see if there are any other correlations.

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von Hippel, E. (1988), *The Source of Innovation.* Oxford University Press, New York.

APPENDIX A

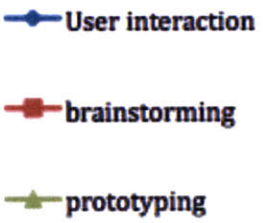
online time sheet filled out by individual students at the end of a milestone.

Name	
Email address	
Athena name	

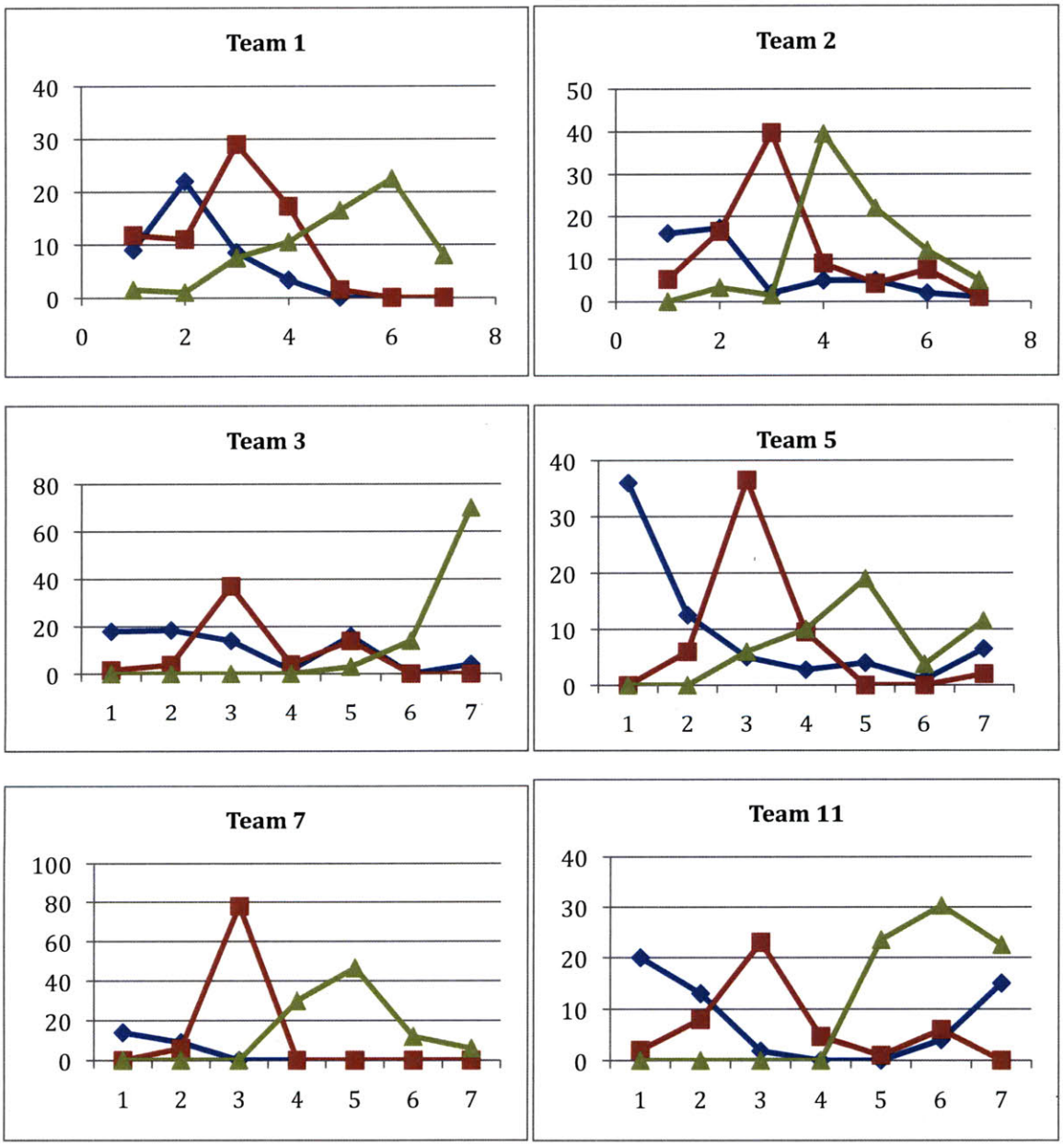
Activity	Time spent	Comments
User Market Research: Investigating or identifying markets, customers, or users through interviews and other techniques. Includes user testing.	hours minutes	
Concept Generation: Formulating design solutions, i.e. brainstorming.	hours minutes	
Concept Selection: Evaluating and choosing concepts (includes product testing).	hours minutes	
Design: Planning the details of your concept and how it will function and look.	hours minutes	
Building: Fabricating or coding a concept. Includes prototyping and working with vendors.	hours minutes	
Business Plan: Planning future development and financial projections.	hours minutes	
Class: Attending or viewing class.	hours minutes	
Presentation Preparation: Preparing for team presentations.	hours minutes	
Meetings: Scheduling and managing meetings. Includes time spent in meetings that does *not* involve the first 6 activities above.	hours minutes	
Other: Please explain.	hours minutes	

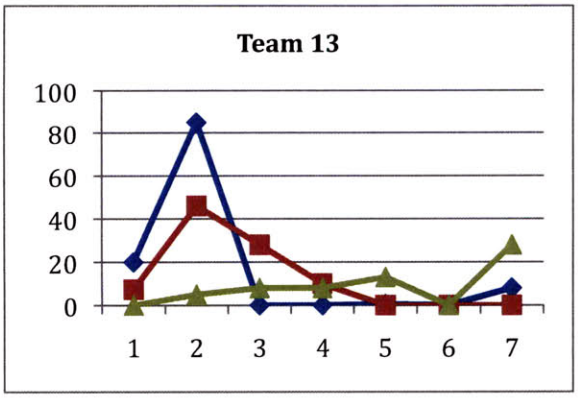
Submit Timesheet Entry >>

APPENDIX B



The following graphs show how much time each of the team spent on user interaction, brainstorming, and prototyping during each of milestones 1 through 7.

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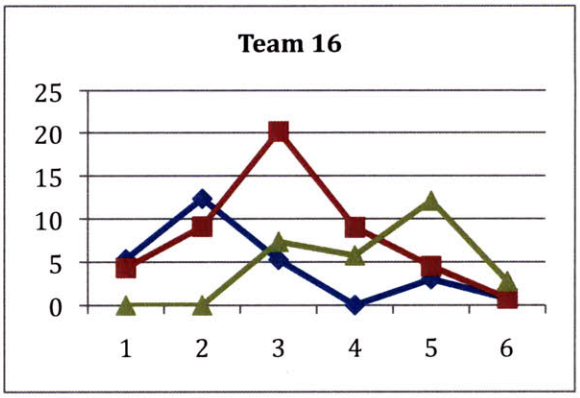
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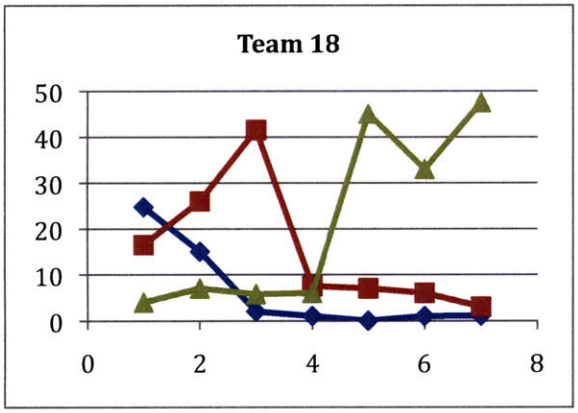
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