

Implementing Design Tools in Capstone Design Projects: Requirements Elicitation Through Use of Personas

Beshoy Morkos, Joshua D. Summers
Clemson University

This paper discusses the difficulties encountered when a team of Mechanical Engineering students attempt to elicit requirements during their Capstone Design Project. Specifically, the students attempt to elicit requirements for handicapped individual, users of whom they could not empathize with. To assist the students, they are introduced to the use of personas as a design tool. Through the use of such a design tool, make significant gains in their requirement elicitation efforts. Furthermore, the students are able to possess a much greater understanding of the design problem and the users of the device. Upon completing the project, the students are surveyed on their experience to elicit requirements and the difference encountered when making use of a design tool. The findings in this paper encourage students to explore the use of design tools and for professors to make aware to students the host of design tools available for their use.

Corresponding Author: Joshua D. Summers, jsummer@clemson.edu

Introduction

This paper entails a study on a Senior Capstone Design project performed by a team of five students in the Mechanical Engineering Department of Clemson University. The author of the paper acted as a design coach to the students and aided the students throughout the semester in various design applications. This paper discusses the difficulty the students encountered in eliciting design requirements for users in which they were not familiar with and how the students were able to use specific design tools to assist in this.

The students were given a problem in which they were to design a headrest for a handicapped individual for use within a vehicle. The students encountered great difficulty in developing requirements for such use as they could not empathize with handicapped individuals. This paper will discuss the struggles the students encountered in developing an accurate set of requirements that reflected the needs of the user. Additionally, the paper will discuss how the students used personas to assist in dealing with such a problem.

Course Background

The Senior Capstone Design course at Clemson University consists of semester long projects that are distributed to students. Each project consists of multiple groups, each of four to five students. The students may select a specific individual to work with within their group or may request a specific project to work on. In an effort to even the skill-sets amongst the groups, the students provide the course professor information regarding their work experience and capabilities in different engineering design categories (i.e. analytical,

modeling and prototyping abilities) to assist when forming groups. Students are grouped based on their abilities as to try to evenly distribute group capabilities.

Design Statement and Problem

This specific project required the students to design and develop a headrest system for handicapped individuals. The design statement given to the group stated:

“Design a device that provides head and spinal support for a handicapped individual which affords crash safety and general comfort for use in a vehicle”

This problem was selected as, currently, no viable solution for handicapped individuals who wish to attach a headrest for spinal support while driving a vehicle exists. The students are responsible for ensuring the headrest meets all vehicle and safety regulations regarding vehicle headrests so that it may possess adequate support to its users

The team’s task was to develop a headrest for a wheelchair that could be used in an automotive vehicle and could survive and protect the user during an accident. The design selected required sufficient robustness to ensure any handicapped individual could use the product, regardless of their condition.

Accordingly, students are to perform analysis on the system to ensure it is capable of providing the spinal support needed to pass regulations. Alongside the finite element analysis performed, the students are to build prototypes for visual and/or testing purposes.

The project spanned an entire school semester, approximately four months. The deliverables for the

design included a functional prototype and the appropriate supporting documentation.

Design Team

The design team consisted of five senior students; four male and one female. All the students had, at one point throughout their academic tenure, participated in an internship or co-op. The students within the group shared complimentary skills as the group consisted of individuals who were proficient at finite element analysis, analytical calculations, manufacturing and documenting.

Developing a Set of Requirements

This was the first experience the students encountered with developing such a system. The students were not familiar with regulations pertaining to headrests and their development. The students were aware of the basic functionality of a headrest based on their experience with the mechanics of a headrest and the forces it encounters. However, the students used their limited knowledge to assume system capabilities.

During the initial stages of the project, the clarification of tasks, the students aimed at trying to understand what a handicapped individual would wish to have from such a headrest system. This phase of the design process allowed the team to collect information about the requirements that have to be fulfilled by the product and any existing constraints¹. Their initial primary questions of interest were:

- *Would a person on a wheelchair prefer the device be a fixed element of the vehicle or a removable component?*
- *What are some of the difficulties encountered entering and exiting the vehicle? Are there any challenges faced that can be compounded by a fixed component in the vehicle?*
- *Does the support need to be adjustable for different driving conditions?*

As seen from the initial questions posed, the design team needed information on the needs of a handicapped individual. The design team struggled in developing requirements for a product to be used by a handicapped individual. The students were not aware of the needs a handicapped individual would need from a headrest. They understood there was a need for such a device on the market; however their knowledge on requirements of handicapped individuals was limited. The team could not accurately develop a requirement list.

The document most influential to the design project was the requirement list. Requirements analysis is the process of identifying a user's needs and determining what to build in a system². The requirement list included

all explicit and implicit requirements the product had to satisfy³. Without an accurate set of requirements, the team would struggle in many subsequent design activities as the requirements process supports many activities within the design process. The process of identifying needs is an integral part of the larger product development process⁴. In developing their original set of requirements, the students used the design knowledge they had gained through their undergraduate design classes to develop a rudimentary requirement lists.

In order to successfully complete the design project, the design team had to gain an understanding of handicapped users of different physical conditions so all their needs could be taken into consideration during the design of the final product. Initially, the design team used personal preference in trying to determine the appropriate requirements for the wheelchair. This included viewing the requirements of headrests on vehicles and those currently on wheelchairs and what they "thought" would be needed from a wheelchair headrest if used within a vehicle. Approximately one month into the semester, the group had generated seven requirements. These requirements were of basic design knowledge, their perception of the needs and any resources they could find online or at the library. The initial set of requirements stated:

- Fits on vehicle
- As light weight as possible
- Pass or exceed governmental crash test standard
- Be manually operated
- Not limit or interfere with entry or exit from vehicle
- Be comfortable for passenger
- Provide head support

While there was no recommendation as to the number of requirements needed, the team was notified by the Advisory Committee (those professors who oversaw team progress) their requirements were not sufficient in moving forward within the design process as it lacked any pertinent information. Specifically the requirements were very abstract. The requirements did not give the team adequate information to start the ideation process and generate concept.

Implementing Persona Design Tool

In order to successfully generate a set of requirements the team may use in designing and developing a headrest, a greater understanding for handicapped individuals was needed. It is well known researchers have linked the problem with insufficient requirements to poor communication among designers and users⁵. After suggestions from the design coach, the students made use of a persona. A persona is a user whose goals and needs are representative of a particular group of

people⁶. The team used a persona to help in collecting data to develop suitable requirements. To help develop a persona, Kim, a handicapped individual, assisted the students. The students use a persona so they may have a greater understanding of the everyday life of the typical product user.

Kim assisted in the team by providing the team with information such as the flow of her day, her capabilities and environments. The team was given guidance as to how to use a persona to assist them in developing their set of requirements. A persona does not provide requirements for a system. Rather, a persona is a source for which the students could extract useful raw data. A good persona description is not a list of tasks or duties; it is a narrative that describes the flow of someone's day. Additionally, a persona answers critical questions that a job description or task list does not, such as: which pieces of information are required at what points in the day⁷. Additionally, this raw data must be translated into engineering specifications as the persona may not be a designer or engineer. This is important as the customer raw data will not always provide the designer with sufficient, accurate, and technical information as to what each component of the system must satisfy⁸.

Final Requirement List Elicited

Through assistance from Kim, the team was able to develop an accurate requirement list. The completed requirement list was able to assist the group in making executive decisions during the remainder of the semester as the team had a clear understanding of the design problem, and more importantly, the handicapped individual using the product. Kim was able to provide the team with much information including her wheelchair, as seen in Figure 1, for measurements and data collection.



Figure 1: Kim's Wheelchair

Kim was able to provide the design team with information regarding her everyday activity which would have an impact on her headrest use. Using this information and continuous iterations of requirement elicitation, Kim was able to assist the team in

developing a set of requirements that accurately reflected the needs of a handicapped individual.

The final set of requirements is shown in Table 1. Many more requirements were added to the requirement list. Additionally, many of the original requirements were further detailed based on input from Kim. For example, the requirement regarding providing head support was extending to providing both head and shoulder support. This requirement was suggested by Kim as she stated that when driving, she requires support in multiple areas of her upper body, not simply her head. This is an example of a requirement the team would not have been able to elicit without assistance.

With the greater knowledge the team possessed of the design project, the requirements were also segmented into constraints and criteria. The constraints were those requirements the team felt a handicapped individual must possess, while the criteria were those requirements that were not needed, but would be desirable.

Table 1: Final Requirements

Constraint	Require no vehicle modification
	Weigh no more than 15% of initial chair weight
	Last 20+ years (lifetime of chair)
	Meet or exceed the WC-19 standard for wheelchair performance in a crash test
	Require the assistance of no more than one additional person to operate
	Not limit or interfere with entry or exit from vehicle
	Not adversely affect comfort of the user
	Provide support for the head and shoulders of the user
	Must lay within confines of wheelchair
Criteria	Be as light as possible
	Be aesthetically pleasing to the majority of a sample audience
	Have a target retail cost of less than \$500
	Enhance the ride comfort of the user in a vehicle and in daily activities
	Be as small as possible
	Affect wheelchair balance as little as possible

Initially the team used Kim as their person of interest for questions. The team also used Kim for prototype recommendations. For instance, when the design team developed prototypes, such as that seen in Figure 2, they placed the prototype on Kim's chair to view her input on the headrest. This input would then be translated to further requirement iterations. Due to continuous requests to consult with Kim, the team developed a persona modeled after her. This persona captured all the needs of Kim so the team could make reasonable assumptions during design decisions.



Figure 2: Prototype Wheelchair Headrest

Discussion and Survey

A survey was conducted with the students at the end of the semester to discuss their experience with eliciting requirements. This survey focused on their experience developing requirements for a user they cannot empathize with. The students in the team were asked how they generated the requirements and what tools they found to be useful. The students commented their own needs and preferences influenced requirement elicitation. This was primarily due to their inability to relate to a handicapped individual. In doing so, the students stated they imagined themselves in the role of a handicapped individual and tried to think as to what a handicapped individual would need from such a device. Under their own admittance, the students stated that this was not wise design practice, but were left with little choice under strict deadlines.

The students stated the use of a design tool was very helpful in eliciting a list of requirements. The students stated they would have eventually consulted the help of a handicapped individual, but developing a persona of an individual so they are not needed at all times was wise. The team stated they were able to view other project which used personas and try to implement a persona into their group similarly.

Conclusion

This paper discussed the difficulties encountered when a team of students attempted to elicit requirements for a handicapped individual they could not empathize with. The group's lack of knowledge on the user caused many incorrect needs in their requirement lists. The individual who aided the group, Kim, stated to the students that many of their original requirements contained errors and misperceptions. Kim also helped the students develop a persona so they may have a better understanding of the user during requirements elicitation. After many iterations of the requirement list, the team and Kim were satisfied with the set of requirements developed.

It is important to note the design team was not given a persona, Kim, and then told to use her. Rather, the team was required to investigate how to use a persona and proper means of collecting information from a persona. This is very important as Kim is not a designer nor can she assist the students in directly designing a headrest. She merely suggests to students specific details. It was the responsibility of the team to explore the design tool and how to specifically use the design tool appropriately. Likewise, Kim is not considered a persona, but an individual who helped the team develop a persona for handicapped individuals. The team initially treated Kim as a persona, but as they began to have a greater understanding for handicapped individuals, shifted toward developing a persona.

The key takeaway of this paper is the importance of introducing students to different design tools throughout projects such as this. In this case, the importance of human user interaction during the design process was critical to the success of the students. Many design tools exist, each with a different purpose, which could assist capstone students. Due to their lack of experience, many students are not familiar with design theory or the tools available at their disposal. Such awareness could make great strides in capstone courses for our future designers and engineers.

References

1. G. Pahl and W. Beitz, *Engineering Design: A Systematic Approach*, 2nd ed.: Springer, 1998.
2. S. Diev, "Requirements Development As a Modeling Activity," *ACM SIGSOFT Software Engineering Notes*, vol. 32, no. 2, March 2007.
3. Z. Y. Chen, S. Yao, J. Q. Lin, Y. Zeng, and A. Eberlein, "Formalisation of product requirements: from natural language descriptions to formal specifications," *International Journal of Manufacturing Research*, vol. 2, no. 3, pp. 362-387, 2007.
4. K. T. Ulrich and S. D. Eppinger, *Product Design and Development*, 1th ed.: McGraw Hill, 1995.
5. E. W. Duggan, "Generating Systems Requirements With Facilitated Group Techniques," *Human Computer Interaction*, vol. 18, p. 373-394, 2003.
6. S. Leritz-Higgins, "Practicing Persona Development: an In-house Case Study," in *Usability and Information Design*, 2004, pp. 350-355.
7. K. Goodwin. (2001) Cooper Design. [Online]. http://www.cooper.com/journal/2001/08/perfecting_your_personas.html
8. B. Morkos and J. Summers, "Elicitation and Development of Requirements Through Integrated Methods," in *International Design Engineering Technical Conference*, San Diego, 2009