DEVELOPING A GRAVITY-POWERED LIGHT SOURCE FOR SUSTAINABLE AND PORTABLE USE

ANALYZING THE EFFICACY OF USER-CENTERED DESIGN IN THE DEVELOPMENT OF DISTRUPTIVE TECHNOLOGIES

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Mechanical Engineering

By
Arthur W. Hofer

October 31, 2019

Technical Project Team Members
Danny Beatty
Brody Hicks
Nathan Tumperi
Will Tyree

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

Signed: Arthur Hofer Date: Dec 6, 2019

Approved: __________ Date: Jan. 22, 2020
Michael E. Gorman, STS Division, Department of Engineering and Society

Approved: M. E. Momot Date: Dec 5, 2019
Michael Momot, Department of Mechanical and Aerospace Engineering

USER-CENTERED DESIGN AS HARMFUL

The principles of user-centered design have nearly become dogma in the design world, and this is dangerous. When principles are accepted without question, people tend to misapply the principles and make false assumptions. Many truly innovative and groundbreaking technologies have been developed without user-centered design (Norman, 2005), begging the question, “How necessary are the principles of user-centered design to disruptive technologies?” The principles of user-centered design should be readdressed to determine if and how they apply to the design of disruptive technologies.

Over the past half century, psychologists and designers have joined forces to analyze the design process from a psychological perspective. From this effort various design methodologies have emerged which claim to improve the efficacy of final products. Common among these methodologies is a focus on the end user, which is known as “user-centered design.” This focus manifests itself in user interviews, defining user’s needs, incorporating users into the ideation process, and testing products against user feedback (Norman, 2013). While a focus on the user has been shown to result in more successful products across industries (Gabbard, 1999; McCurdie, 2012), user-centered design may also stifle innovation and creativity. Too much focus on the user can lead designers to rely too much on positive feedback or “design by committee” rather than on their own intuition and creativity. Where user-centered design attempts to design around the current state of users, groundbreaking innovations are highly disruptive (for the good) and force society to mold around them instead (Sirk, 2019). These ideas may never make it to the light of day if they had to first spring from the limited universe of ideas deemed useful by users. Furthermore, if too much time and energy is given to user-based research, innovation may be slowed or stifled by the additional time and cost of following the user-centered methodology

(Lofthouse, 2006). Different styles of design may be more effective and less costly than user-centered design.

For my Capstone, I am working on a team to design a human-powered light source using the gravitational potential energy of a falling weight. This project is being conducted without user-centered design. Instead, the Capstone team is using activity-centered design by relying on our intuition and common knowledge to determine design requirements. The results of the project will be used to test whether successful products can be designed without implementing user-centered design.

DESIGNING A HUMAN-POWERED LIGHT SOURCE USING ACTIVITY-CENTERED DESIGN

Human power has been considered an alternative and sustainable energy source for many years (Jansen 1999); however, its adoption has been slow. While human power will not be able to supply near the amount of energy needed to replace energy sources like fossil fuels, it can be used to make more sustainable products by eliminating the need for high power and pollutive batteries (Anthony, 2012). When considering possible uses of human energy, the Capstone team decided to focus on powering a light source because this is a low power but highly useful application. Human-powered light sources are commonplace, mostly in the form of hand-crank flashlights. These flashlights require constant energy input and constant human exertion. They are largely reserved for emergency situations when electricity and batteries are not readily available. Therefore, they are not desirable over the convenience of battery-powered flashlights. The Capstone team asserted that creating a light source that did not require constant energy input from the user may be more desirable and readily adopted. Therefore, the Capstone team decided to pursue a light source powered by the potential energy of a slow falling weight. The concept allows the user to exert energy by lifting a weight to a starting position and leave the system to generate electricity from the potential energy of the falling weight.

Research into the product space revealed that Deciwatt Ltd. has produced a light, called GravityLight, which functions in this manner, harvesting energy from a falling weight. However, this application was designed for communities that lack reliable access to electricity. For example, the GravityLight is not easily transported and is intended to be mounted in a permanent location (Deciwatt, 2019). Our intended users will live in communities that have ready access to electricity, so the Capstone team decided to focus on specific applications that require remote electric power. Therefore, our use case is outdoor lighting in areas without electricity. More specifically, we are designing the light to be used by backpackers at the campsite. Therefore, we are minimizing the weight and size of the product to accommodate the perceived needs of backpackers. In use, the light will be attached to the trunk of a tree using a tightening strap such that the light is elevated off the ground allowing the weight to fall and power the light. The weight will be hung using a cord which drives an electric generator through a mechanically disadvantaged gearbox. This will allow the weight to fall at a low speed while generating sufficient electricity to power an LED light source. Our goal is to power a 150-lumen light source for 20 minutes by lifting a 20lb weight 5 feet.

The design as described has been created through the intuition, prior experience, and creativity of the Capstone team. This design process follows the principles of activity-centered design, whereby designers determine the activities a user will perform *a priori* and design the system to achieve the core functionalities (Spool, 2009). We understand that there are assumptions being made; for example, users may not be willing to lift the weight repeatedly to power the light. However, such assumptions may be acceptable given that this type of technology is not widely adopted. Society and potential users may not place enough value on human generated electricity to deem this product worth the additional human exertion. As our society begins to experiment with the potential for harnessing human-generated electricity, our value system may change, reducing the barriers to entry of new human-powered products (McVey, 2017).

USER-CENTERED DESIGN DOES NOT ACCOUNT FOR TECHNOLOGY'S IMPACT ON SOCIETY

User-centered design has been fanatically adopted by many industries wishing to label themselves as modern and in-touch with current design trends (Chochoiek, 2017). However, a myopic focus on user centered design may lead designers to miss leaps in innovation which cannot result from simply studying the user. User-centered design was widely popularized by Donald Norman's book *User-Centered System Design: New Perspectives on Human-Computer Interaction* published in 1986. Norman advocated prioritizing empathy with the user over the functionality or aesthetics of design. He suggested conducting research in order to identify user needs and discover how a user interacts with a design. This will lead the designers to empathize with their users and to design solutions that maximize the user's enjoyment of the design (Norman, 1986). Norman's theories were widely supported by case studies of common design failures. In his book, *The Design of Everyday Things*, Norman analyzes design failures such as doors which are confusing to open. As the title suggests, these principles apply well to everyday things (Norman, 1988). However, these principles may not be as applicable to highly innovative technologies.

According to the Actor-Network Theory, technologies and humans can affect each other as equal actors (Muniesa, 2015). User-centered design may too often assume that technologies should conform to the pre-existing mental models in society. Actor Network Theory would suggest that the technologies will inherently change the society in which they exist. Therefore, basing technology on the current society could be nearsighted, as good design or beneficial technology will prompt society to change in response to the technology. This consideration may be unnecessary when it comes to redesigning everyday things. These technologies have already made their impact on society and a slight change in design may have a negligible impact on society. By contrast, highly innovative or disruptive technologies should be expected to change the societal context in which they exist. Therefore, the designs should not be so heavily tailored to the current mental models of users. For example, designs which promote ecological sustainability often require people and society to adopt new value systems to achieve success (McVey, 2017). Sustainability often comes at a cost to the user, either directly through higher prices or by demanding additional effort. The users must value the ecological benefits enough to be willing to pay the additional cost. This change in the value system may only come once the new designs have been normalized through an adoption period. User-centered design fails to account for benefits to society at large by focusing excessively on the individual user.

CASE STUDIES OF DISRUPTIVE TECHNOLOGIES

I propose to research the efficacy of user-centered design in the context of innovative and disruptive technologies. Since design is inherently abstract, it has proven difficult to find quantitative research into user-centered design. Therefore, I plan to use case studies to provide anecdotal evidence for my research question. I intend to use three case studies into different disruptive technologies, namely the automobile, the smartphone, and online classifieds. More specifically, I will be looking into the successes of the Ford Model-T, the Apple iPhone, and Craigslist.org. Preliminary research shows that these products may have been developed with methodologies that are at odds with user-centered design. The Ford Model-T became one of the most successful automobiles of all time because Henry Ford focused on building a reliable automobile while minimizing the cost, even when it went against the desires of the users (Vlaskovits, 2014). This resembles activity-centered design, whereby the designers focused on key functionalities over the desires of the user (Spool, 2009). The iPhone, while one of the most successful consumer products of all time, was not developed using user-centered design, but the designers prioritized aesthetics and simplicity (Norman, 2018). This resembles genius design, whereby an experienced designer (Steve Jobs, Jony Ive) creates a product from their vast previous experience (Spool, 2009). Craigslist was originally an email newsletter created by Craig Newmark out of his own desire to meet-up with friends and find events, and it unintentionally grew into one of the 20 most popular websites in America (Sheppard, 2019). This resembles self design, whereby a designer is simply looking to fulfill their own needs (Spool, 2009). These cases will be further analyzed to determine which design methodologies were most closely followed. Ultimately, a conclusion will be drawn as to how user-centered design played a role in the successes of the products or if the use of user-centered design would have stifled their success.

I will use Actor Network Theory to analyze the various actors in the design of the Ford Model-T, the Apple iPhone and Craigslist.org in order to identify what factors led to the successes of these products. Actor Network Theory will shed light on how the designers were influenced by the various actors to help determine which design methodologies were being used in the design of these disruptive technologies. Conclusions will then be drawn as to if and how user-centered design fits into the design of disruptive technologies.

CONCLUSION

User-centered design has proven to be an effective means of improving user engagement by designing towards the needs of the users. However, user-centered design is not appropriate in all cases and should not be seen as the sole key to successful product design (Norman, 2005). While many products will benefit from increased understanding of the user and usability tests, it may be more effective to design early stage technologies with design methodologies such as activity-centered design, genius design, or self design (Spool, 2009). The cases studies noted above will serve as anecdotal evidence for this theory. Furthermore, the Capstone project will be a test of this theory as it is being conducted using activity-centered design rather than user-centered design. Since implementing human-powered electricity may require a change in society's value system, it may be more effective to design towards the function of the device before weighing it against the user's experience of the device. If the Capstone produces a human-powered flashlight that is able to test a functional concept without the burden of addressing users' needs, it will advance this technology and may be a first step in its wider societal adoption.

WORKS CITED

Anthony, S. (2012, September 7). Will your body be the battery of the future? Retrieved November 1, 2019, from https://www.extremetech.com/extreme/135481-will-your-body-be-the-battery-of-the-future.

Chochoiek, N. (2017). Explaining the Success of User-Centered Design - An Empirical Study across German B2C Firms. *Junior Management Science*, *2*(1), 81-116. doi: 10.5282/jums/v2i1pp81-116

Deciwatt Ltd. (2019). GravityLight - light from the lift of a weight. Retrieved November 1, 2019, from https://deciwatt.global/gravitylight.

Gabbard, J., Hix, D., & Swan, J. (1999). User-centered design and evaluation of virtual environments. *IEEE Computer Graphics and Applications*, *19*(6), 51–59. doi: 10.1109/38.799740

Jansen, A. J., & Stevels, A. (1999). Human power, a sustainable option for electronics. *Proceedings of the 1999 IEEE International Symposium on Electronics and the Environment (Cat. No.99CH36357)*. doi: 10.1109/isee.1999.765878

McCurdie, T., Taneva, S., Casselman, M., Yeung, M., McDaniel, C., Ho, W., & Cafazzo, J. (2012). mHealth Consumer Apps: The Case for User-Centered Design. *Biomedical Instrumentation & Technology*, *46*(s2), 49–56. doi: 10.2345/0899-8205-46.s2.49

McVey, E. (2017, February 9). A Critique of User Centered Design: Have UCD Practices Hindered an Ecologically Sustainable Future? Retrieved November 1, 2019, from https://medium.com/@eilishmcvey/a-critique-of-user-centered-design-have-ucd-practices-hindered-an-ecologically-sustainable-future-da0c2b1c2ef8.

Muniesa, F. (2015). Actor-Network Theory. *International Encyclopedia of the Social & Behavioral Sciences*, 80–84. doi: 10.1016/b978-0-08-097086-8.85001-1

Norman, D. A., & Draper, S. W. (1986). *User centered system design: new perspectives on human-computer interaction*. Hillsdale, NJ: Lawrence Erlbaum.

Norman, D. A. (1988). *The design of everyday things*. London: Basic.

Norman, D. A. (2005). Human-centered design considered harmful. *Interactions*, *12*(4), 14. doi: 10.1145/1070960.1070976

Norman, D., & Tognazzini, B. (2018, July 9). How Apple Is Giving Design A Bad Name. Retrieved December 3, 2019, from https://www.fastcompany.com/3053406/how-apple-is-giving-design-a-bad-name.

Lofthouse, V. A., & Lilley, D. (2006). What They Really, Really Want: User Centered Research Methods for Design. *International Design Conference – Design 2006*.

Sheppard, N. (2019, June 18). Craigslist: success without design. Retrieved December 3, 2019, from https://www.userzoom.com/blog/craigslist-success-without-design/

Sirk, C. (2019, September 4). The Godfather of UX: Don Norman & User-Centered Design. Retrieved from https://crm.org/articles/the-godfather-of-ux-don-norman-user-centered-design.

Spool, J. M., & Vijayashanker, P. (2009, January 21). 5 Design Decision Styles. What's Yours? Retrieved December 4, 2019, from https://articles.uie.com/five_design_decision_styles/.

Vlaskovits, P. (2014, July 23). Henry Ford, Innovation, and That "Faster Horse" Quote. Retrieved November 18, 2019, from https://hbr.org/2011/08/henry-ford-never-said-the-fast.