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Prototyping and Case Study of Sustainable and Ergonomic Toilet Design

H.K. Lee
Division of General Studies, Ulsan National Institute of Science and Technology (UNIST),
50 UNIST-gil, 44919 Ulsan, Republic of Korea

Abstract: This study presents case studies for an innovative function and form of a toilet that would be efficient for ecology and the prototypes and the process of designing a waterless toilet to address the water scarcity issue in the Republic of Korea are described. The ergonomic sitting posture needed for defecating is discussed and the design a waterless toilet is described. This was achieved by conducting focus group interviews with a user engagement approach to understand the needs of users and how to improve the design of a toilet. The results led to the development of an experiential service design project to raise awareness of water scarcity as well as new technology to remove the odor caused by toilets. The research aim was to understand the concept of several features of toilet design and the new paradigm of the production and culture of defecating systems. A descriptive analysis is used to present the current features and how they are implemented. An exploratory analysis was conducted based on the factors of sustainability, ergonomic posture and degree and aesthetic form.

Key words: Waterless toilet, toilet design, prototype of toilet, sustainable product, water scarcity, energy regeneration

INTRODUCTION

The research aim was to understand the concept of several features of toilet designs as well as the new paradigm of the production and culture of defecating systems. The purpose of the data analysis was to investigate whether there is a need to design a waterless toilet, to focus on understanding the cases of innovative toilets that have recently been released and to explore the efficient features and forms of these toilets. The ergonomic sitting posture needed for defecating is described and the potential designs for a waterless toilet are explored. This was achieved by conducting focus group interviews with a user engagement approach to understand user's needs and how to improve the design of a toilet. The results led to the development of an experiential service design project to raise awareness of water scarcity and to new technology used to remove the odor caused by toilets.

The bathroom is one of the most important spaces in a public space or house. According to the World Toilet Organization, people use toilets 2.500 times/year or 6-8 times daily. The conventional toilet system which is the flush type has helped protect humans from waterborne diseases and has improved public health. Although, the water disconnects people from their excreta, this causes environmental problems, especially, in terms of water pollution. People flush their excreta without being aware of the massive pollutant flow to the environment. Therefore, creating a comfortable and cleaner space is essential for public places such as restaurants, hospitals, supermarkets and malls, however, most public restrooms are dissatisfactory and do not provide pleasant and comfortable experiences. A major cause of dissatisfaction is that people fear contact with germs. Therefore, a novel, waterless-safe toilet is needed to respond to discontent and to the water scarcity problem. This was achieved by conducting focus group interviews with a user engagement approach to understand the needs of users and to improve the toilet design.

Literature review: This study reviews previous research data and case studies for innovative functions and forms of toilets that would be ecologically efficient and the prototypes and processes of designing a waterless toilet to respond to the water scarcity problem are described.

MATERIALS AND METHODS

To design toilets and improve the experiences of toilet spaces, community engagement is a suitable approach to obtain insight and to develop appropriate solutions for users. The Fuzzy Front End stage (FFE) of designing a better toilet experience was implemented for this study and a collaborative research project between designers and scientists was conducted. The aim of the collaboration team was not only to create a better toilet space experience but also to raise community awareness

of water scarcity. The user-centered approach with the community allowed for co-designing the waterless toilet at the FFE. The user centered approach influenced co-designing waterless toilet project to turn into two projects to meet each need from technology push nature: one for future toilet users in the community and the other for participants to conserve water and solve the water scarcity problem. In addition, better toilet space experiences result from a sense of hygiene and cleanness.

For the design to be meaningful to users, it is important to understand user experiences and perceptions as well as the way people make sense of things (Krippendorff, 1989). A thorough understanding of the target users and their needs is necessary for a successful design. Therefore, the aim was to collaborate with the people in the community who would be future users of the waterless toilet which is a reflective problem-solving approach used to design prototypes (Schon, 1983).

The study aim was to understand the needs of the people in the community where the test-bed research lab will be built at UNIST campus. A total of 54 participants (15 females and 39 males) who had used public toilets as well as those in their homes and who would be potential users of the waterless toilet prototype were included in the focus group interviews. There were 9 groups. Each group was comprised of six undergraduate students at UNIST majoring in different engineering areas such as life science, chemical engineering, physics, computer engineering, electronic engineering, mechanical engineering and engineering management.

To ensure that all key issues were addressed, semi-structured interview questions were used. The participants were asked about their awareness of water scarcity in the country, their previous experiences of attempting to conserve water, the ways they would be motivated to conserve water, their perceptions of a waterless toilet and their ideal toilet design. They were also asked to share their thoughts and ideas regarding water conservation. All interviews were audio recorded and memos were taken and later analyzed using a thematic analysis. All participants in each group had different majors but all shared common ideas and perceptions for each question. Through the thematic analysis, three categories emerged: disbelief regarding water scarcity, motivation to conserve water and an experience requirement for the waterless toilet. Based on the results of the focus group interviews, it was evident that although, the participants were aware of the water scarcity problem, they had not tried to conserve water because they could access water easily at their convenience. A design activity exposed new issues and information as the work progressed (Lawson, 2005, Loch *et al*., 2006).

Fig. 1: Wellbeing toilet (Anonymous, 2018a)

Wellbeing toilet: A new type of toilet was designed by three industrial designers from Central Saint Martins in the UK: Sam Sheard, Pierre Papet and Victor Johansson. They discovered that the ideal posture of raising the legs is awkward and that people lack awareness of the new posture in the western culture while in other cultures, the ideal posture is understood. In addition, the squat posture is not easy to maintain. Thus, they designed the Wellbeing toilet which users must step up to reach and then draw their knees up. Figure 1 presents the Wellbeing toilet which is a hybrid between a typical flushable toilet and a traditional toilet. It is currently only a concept design but they designed the toilet to analyze user's urine for diagnosing diabetes. Many people need to pay much more money because they are diagnosed their diabetes later. By checking up the diabetes not in the hospital but in their toilet, it will be helpful to catch diseases earlier. In terms of pee test, the home pregnancy test and nutritional deficiencies check can be analyzed by the new toilet. The designers also included a system that uses gray water. Because the design of the toilet is unfamiliar, users may have negative perceptions. The goal of the designers was to use the toilet in a healthcare environment along with other healthcare equipment. Because people who use spas or gyms tend to be health-conscious, they would likely accept this new ergonomic toilet more readily than other users.

Easy squatty: Rather than replacing an existing toilet in the home, buying a foot rest for an ideal posture is much easier for the public. The easy squatty is a footrest product and it is lightweight and inexpensive. It can be

Fig. 2: Retrieved from; https://www.desertcart.ae/products/14438952-easy-squatty-provides-you-healthy-toilet-posture-effortless-bowel-movement-recommended-by-physicians-ergonomic-design-lightweight

useful in the process of changing toilet habits. People can experience the benefit of the squat posture for better bowel movements using this simple tool. Once they experience the difference, they will use the squat posture toilet, although, it is an unfamiliar design (Fig. 2).

Loowatt, waterless toilet: The Loowatt toilet uses biodegradable film to eliminate human waste instead of using water for flushing. It has a simple and efficient sealing technology which is patented. The sealed waste is stored in a cartridge for a few hours or a few days, depending on the level of toilet usage. The toilet is designed to provide a safe and secure place for women and children and it is used in emergency situations in developing countries such as India. The Loowatt is suitable toilet for these circumstances because it does not require public utilities such as a water supply. In other words, it is off-the-grid and eco-friendly.

The toilet does not require electricity for its sealing and storage system because it generates a bioenergy. It is linked to an anaerobic digestion system to provide a source of biogas. In this system, human waste in the

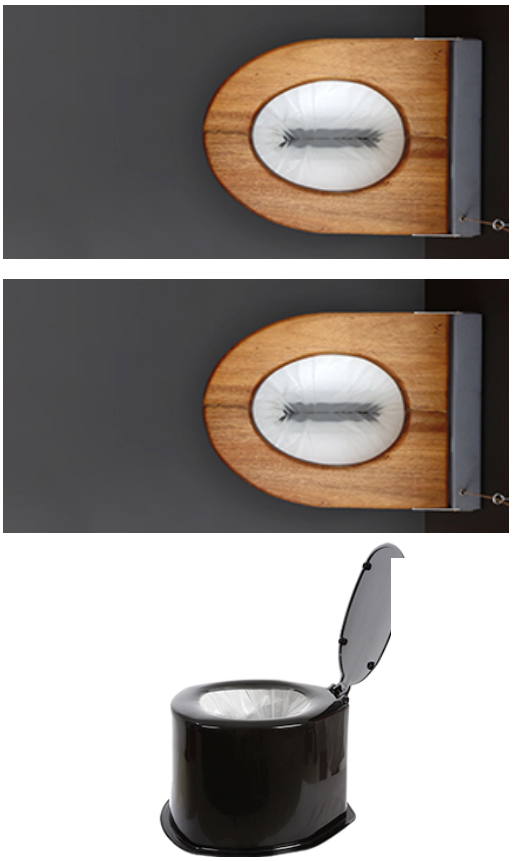

Fig. 3: Retrieved from https://loowatt.com/; (Anonymous, 2018b)

anaerobic digestion system becomes biogas and fertilizer. Anaerobic digestion is a biological process that uses micro-organisms in oxygen-free environments to consume organic waste. The biogas is released from the waste while it decomposes. The pure biogas from the waste contains methane, carbon dioxide and other gases, so, a specific process is required. Methane combusts completely and only water vapor and carbon dioxide remain. After discharging the biogas, the waste becomes a fertilizer called manure. The manure is a semi-liquid and it is easier for plants to absorb.

The Loowatt has huge potential in terms of waterless toilet design because a biodegradable film is used and energy is generated instead of using other sources such as water and electricity. A waterless toilet has critical hygiene issues; however, for the Loowatt, the inside of the bowl is covered with biodegradable film which is then sealed. Thus, the bowl of the toilet is not contaminated and a clean toilet can be used each time. Figure 3 presents an illustration of the Loowatt toilet.

Fig. 4: Retrieved from; http://ghildush.ro/gallery/hytoi/

RESULTS AND DISCUSSION

HYTOI quick dispenser: In public restrooms, a major problem for users is sitting on the toilet which might carry germs or viruses. HYTOI uses biodegradable disposable paper as seat covers for toilets. Of course, it is already an existing one but it is different in terms of usability. Traditional seat cover paper is also used in a dispenser form but it cannot completely cover the seat and does fit easily over the seat. It also moves during use. HYTOI Quick Dispenser allows users to easily apply the seat cover by pulling the paper from the dispenser. The dispenser is located at the backside of the seat and it is connected to the seat which is designed by same company. The paper fits perfectly over the seat.

The seat also has a spring mechanism, so, when users want to move it up or down, it moves softly. There is a lever that can be used to move the seat up or down so users do not touch the seat (Fig. 4).

Automatic self-cleaning toilet seat: A hygienic toilet seat cover is required because public restrooms involve serious hygiene issues. People can clean the seats with tissue and water but it is time-consuming. Even after cleaning, people avoid contact with toilet seats, so, they use paper towels or stand. There are various types of autocleaning seat covers. Among them, a plastic cover changer is a popular toilet cover. The plastic roll covers the seat and the cover is replaced by rolling a new plastic cover from the roll. For another self-cleaning type of toilet, an entire seat can be cleaned by a washer installed in the toilet. After using the toilet, the toilet seat automatically enters the washer. When another user arrives, the seat is released from the washer (Fig. 5).

Fig. 5: Retrieved from; https://www.youtube. com/watch?v=km3xt49fHq4&t=28shttps://www.youtube.com/watch?v=u0Xxg6jNzxc

The sliding lid loo: For this toilet design, the toilet lid is opened differently than traditional toilets. The lid slides up to open. It automatically opens and closes using a distance sensor that detects a user's approach. The lid of a typical toilet can be contaminated when flushing when the water splatters on the lid. People open and sit on the toilet and their backs can make contact with the contaminated lid; however, this new type of sliding lid is free from splattered pollutants. In addition, the lid has a display for showing the user's health information which is detected while the user sits on the toilet. For the ideal posture which is the squat posture, a footstool is provided. The footstool is provided when a user sits and the height is adjustable. This type of automatic technology can provide people with a better toilet space experience (Fig. 6).

A bathroom buddy for the elderly: The designer Jan S. Van Ackeren designed a toilet for the elderly. It has an armrest similar to a chair but it moves up and down when users stand or sit. The armrest ensures safety when sitting and handicapped persons have armrests for support, however, this new type of "buddy" is different because the toilet seat moves. It is more convenient for elderly or handicapped persons because weight is supported by the seat as well, so, there is no need to support the whole

Fig. 6: Retrieved from; http://www.yankodesign.com/2015/07/29/the-sliding-lid-loo/; Anonymous, 2015

Fig. 7: Retrieved from; https://www. yankodesign. com/2017/06/20/a-bathroom-buddy-for-the-elderly/; Anonymous, 2017

body with both arms. When attempting to stand, the toilet pushes users to a standing position by raising the armrest and seat. This type of toilet is better than current toilets designed for handicapped persons because it is space-efficient, cost-effective and adjustable (Fig. 7).

Le Penseur: The Le Penseur toilet was designed by Peter Codling and the name refers to the famous sculpture the thinker. The posture of the thinker is similar to the squat posture. When users can empty their bowels easily in a shorter time, hemorrhoids, pelvic floor damage and even heart attacks can be prevented. The height of this new toilet is slightly shorter than traditional toilets for ideal

Fig. 8:Retrieved from; http://www.dailymail.co.uk/health/article-2348801/Could-toilet-make-healthier-Designer-claims-loo-prevents-disease-makes-squ.html; (Anonymous, 2018c)

Fig. 9: Architecture of sensor node

posture. Because elderly persons and children cannot easily stand due to its height, the designer installed handles for support (Fig. 8).

Prototyping; Waterless toilet design: To design a toilet based on the research of previous cases, three factors were considered: the sanitization function, an ergonomic posture and comfortable aesthetics (Fig. 9).

Sanitization function: First, based on the focus group interviews, it was concluded that people want a clean toilet experience. Thus, the prototype was designed with sanitization (sterilization) and cleanliness in mind. Ultraviolet (UV) lights were installed on the cover so the toilet appeared sanitary. The UV lights also disinfect and sterilize the surface of the seat and the bowl of the toilet (Fig. 9). In addition, because the word “toilette” means

"dressing room" in French, the seat cover was designed to resemble a dressing room vanity chair which was intended to make people feel comfortable. The toilet hip area was designed with enough space for anyone to sit comfortably. Ultimately, the toilet was designed to provide not only a clean experience but also a restful one.

Ergonomic posture: Second, the toilet was designed in an ergonomic manner to support proper posture for defecating. The seat can be adjusted (raised or lowered) to an appropriate angle to fully relax the muscles around the colon and to support quick and easy defecation. Once a user sits on the toilet, the back side of the seat tilts slightly, raising the user's knees. This encourages users to maintain an optimal posture for relaxing the muscles around the colon. The concept for this posture was taken from the Paimio Chair designed by Alvar Aalto for patients in a tuberculosis sanatorium in Finland. When the patient sits and leans on the chair, the patient's posture changes the angle of the chair, helping the patient breathe better and arranging his or her body organs comfortably.

The waterless toilet was also designed ergonomically with respect to the angle of the sitting posture. Although, the tilted seat relaxes the muscles around the colon, it also makes it difficult for users to stand (compared to the upright posture of a traditional toilet). Though this may not pose a significant problem for young and healthy people, it could encumber older, disabled or injured people. Therefore, a spring under the back side of the seat was installed that users can activate by pushing back slightly when they need to stand.

Comfortable aesthetics: Third, the appearance of the toilet prototype was inspired by the white porcelain of the Yi Dynasty (Korean imperial household, called the Joseon household). Toilet shapes have not changed significantly since their initial development in the 16th century, however, this new type of toilet offers several improvements. First, unlike a traditional toilet which has a tapered bowl shape to support a suction mechanism located at its lower-back side, the proposed toilet does not require centrifugal force or a vacuum system to suction feces. Therefore, the waterless toilet can be slimmer or wider. A shape that was comfortable and familiar was chosen. Second, the white porcelain of the Yi Dynasty suggests familiar characteristics of interior objects that already play a role in user's everyday lives which contributes to the aesthetics of the waterless toilet.

This approach can be employed as a project approach guideline to research and resolve public issues. Engaging people in the community helps them identify with current and future public issues. Responding to their opinions, recommendations and insights encourages positive participation for a better public environment. While designing the toilet after researching the previous cases, three factors were considered: the sanitization function, an ergonomic posture and comfortable aesthetics.

CONCLUSION

In this study, the framework for the FFE process of designing a waterless toilet to address the problem of water scarcity in the Republic of Korea has been introduced. Although, the aim was to co-design a waterless toilet prototype based on technology push, the radical technology to remove phosphorus from a toilet encouraged research on user perceptions by design researchers within a collaborative team. Through focus group interviews, key factors regarding water scarcity and perceptions of a waterless toilet were identified: disbelief regarding water scarcity in Korea, motivation to conserve water and experience requirements for the waterless toilet. People generally do not seriously consider the water scarcity issue, however, if they experience water scarcity visually and realistically, they may attempt to conserve water. Simultaneously, people want toilets to be sanitary, odorless, clean and comfortable. This helped reveal user's preferences and the need to improve toilet space experiences and it guided the prototype development to a user-oriented process rather than the rapid development of a technology push process. The user-centered approach with community engagement allowed for obtaining new information for further improvement.

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