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Investigating Design and Deployment of Eco-Feedback Dashboards

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Abstract

This pilot study investigates the design and deployment of an eco-feedback dashboard, use of an eco-feedback dashboard as an educational tool, and the perceived influence of the dashboard on building occupants' behavior. A preliminary survey measured each participant's prior knowledge on sustainability, LEED, personal environmental behavior, and their personal understanding to how a building consumes energy and water and results showed that most participants considered themselves environmentally friendly (79%) and were familiar with sustainability regarding building operation (93%). A postliminary survey after deployment of the eco-feedback showed that all participants (100%) believed that the eco-feedback dashboard helped them learn more about energy consumption but only sixty-three percent (63%) of participants thought the dashboard influenced their behavior to be more environmentally friendly. Findings suggest that eco-feedback dashboards can help building occupants understand energy usage in building operation, but may not increase environmentally-friendly behavior, particularly within a population that has environmental awareness and understanding of energy use in building operation.

Key Words

Eco-feedback dashboard, LEED, sustainability, occupancy behavior, energy consumption

1. Introduction

Operating and maintaining buildings consume around one-third of total energy use, making them a prime target for the application of energy-efficiency measures. Studies have suggested that occupant behavior can have a substantial impact on building energy consumption, which have the potential to reduce US emissions by 7.4% with little or no impact on household well-being. Significant investments have already been made in sensing infrastructures that can provide relevant consumption data, while less attention has gone toward making energy information comprehensible, attractive, and relevant to the building occupants (Paone and Bacher, 2018).

An eco-feedback dashboard (EFD) provides building occupants with information regarding actual building energy consumption. EFDs operate on the premise that building occupants are largely unaware of how much energy is used on a day-to-day basis, and once occupants become aware of their actual consumption, they will take steps to decrease consumption. While numerous factors are associated with the effectiveness and implementation of an EFD, the system's interface design is a key factor in achieving substantial energy reduction. However, research suggests an overall lack of understanding as to which design components are driving the consumption reductions, and which are not. Therefore, which eco-feedback design components are driving resource reduction is crucial to develop interface systems that achieve long-term substantial and sustainable reductions in the built environment (Jain et al., 2012, 2013). Froelich et al. (2010) conducted a meta-analytical study that examined over 100 EFDs and developed design guidelines for EFD interface design, feedback frequency, and information visualization. Since then, Karjalainen (2011) has extended upon this study through the utilization of a rapid prototyping methodology and user surveying to further understand the different user preferences in regard to eco-feedback design components.

This research aims to investigate eco-feedback dashboard design and placement and building occupants' behavior influences on overall electricity and water consumption in a LEED Gold certified building and assessing

visual dashboard methods to proactively influence building occupants' perception of energy and water consumption through the implementation of an EFD.

The objectives and questions driving this research are:

- Evaluate design, information display and interface on an EFD deployed in a building. What engages the user, how do they interact with the system and what information does the user want in an EFD?
- Determine if EFD's influence user behavior and their understanding of building resource consumption (participant reported).
- Determine if an EFD change Building user behavior regarding building resource consumption and if that change in behavior is reflected in the resource consumption data. This was a preliminary goal for additional research.

2. Methodology

This research study was conducted on the campus of Auburn University in Auburn, Alabama, USA during the Summer 2021 through the utilization of a mixed-methods approach. The building in this study is the Gorrie Center Building (GCB), a LEED Gold Certified building that houses the McWhorter School of Building Science, was completed in 2006, is 36,997 gross square feet and provides classrooms, offices, an auditorium and a demo lab for students. The participants were faculty, staff, students and other users of the GCB during the study. Both quantitative and qualitative data were obtained and analyzed through user surveying before and after the implementation of an eco-feedback dashboard (EFD) in the GCB . Research participants were recruited based on their involvement with the GCB in summer 2021. The EFD was displayed on four different TV stands located in various parts of the Building. Anyone within the XX was able to interact with the EFD. The dashboard ran continuously throughout the research period and building occupants were free to observe the display at any time but did not have any ability to influence the active display as the display did not include any interactive features. Only information and data and obtained from the participants completing the pre- and post-surveys were used for this research.

Three weeks after the implementation of the EFD, the postliminary survey was then sent out to the same participant pool within the Building. The postliminary survey sought to validate the effectiveness of the EFD to engage, interact, and educate building occupants on their direct energy and water consumption.

For this study's framework, design interventions included eco-feedback, behavior steering, and persuasive technology. The influential attributes being communicated through these design interventions included attitudes, social attributes, and affection. These attributes may be derived from knowledge, beliefs, subjective values, emotions, etc. Understanding consumer behavior changes and their attributes are imperative for eco-feedback research for they encourage the enhancement or restriction of pro-environmental behavior (Kuo et al., 2018).

2.1 Data Collection Method

1. A preliminary short survey questionnaire to determine participant's current environmental knowledge and behavior surrounding LEED.
2. An EFD was introduced and installed within a common area of the building to encourage user participation and to test influencing ability.
3. A follow-up survey was conducted investigating any change in pro-environmental behavior and eco-feedback design elements that may need to altering for future research.

2.2 Pre-liminary Survey

The preliminary survey consisted of a total of 18 questions. The survey obtained each participant's prior knowledge on sustainability, LEED, personal environmental behavior, understanding of why some people might not participate in pro-environmental behavior, and their understanding of how the building consumes energy and water within a given timeframe. The survey also focused on understanding where the dashboards should be located in the GCB, what information should be displayed on them, and which graphs are easier to comprehend than others.

2.3 Implementation of the EFD

The EFD was streamed through (3) 55" Samsung Smart TVs and (1) 75" Samsung Smart TV. The web-based software will be accessed using (4) Azulle Byte 3 Mini Desktop PCs, which are mounted on the back of each monitor and connected via HDMI cable. The EFD was displayed on four different mobile TV stands throughout the Building (Figure 1).

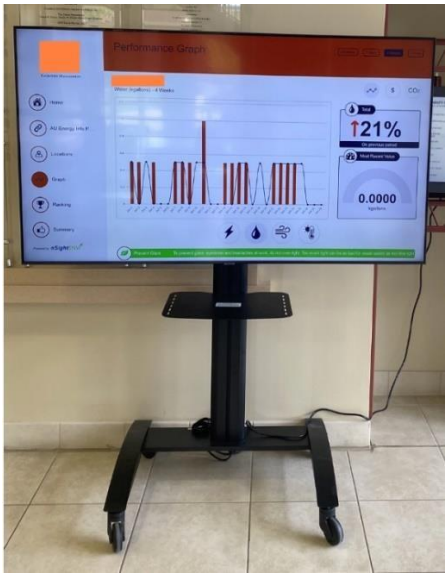

Fig 1. Eco-feedback dashboard deployed in main foyer at main (front) entrance of the XXXXXX XXXXXX

The visual dashboard (Figure 2) transitioned through eleven different display slides displaying the following information:

1. The Building's real-time electricity, water, chilled water, and hot water consumption data.
2. A historical comparison graph illustrating last period's consumption data compared to current, real-time consumption data.
3. Relevant weather information for the location of the building.

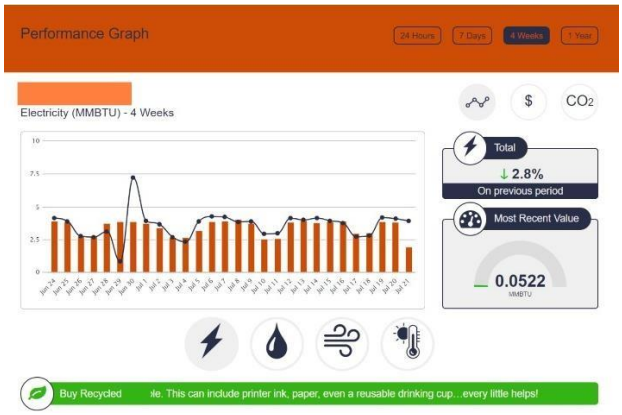

Fig. 2. One of eleven displays looped (30 secs ea.) on dashboard

2.4 Postliminary Survey

The postliminary survey consisted of a total of 12 questions, 3 of which being the screening process. The postliminary survey design intent was to provide feedback and validation to just how effective the EFD was and to understand how

often the occupants engaged and interacted with it. The survey asked questions, such as: how often each participant viewed the dashboard system in a given period, where was the dashboard located when they viewed it the most and did the dashboard system assist in further educating them on how the Gorrie Center Building consumes energy and water. Additional questions asked how the dashboard's design could be changed/altered to attract more viewers and to propose the best location to permanently install an EFD in the building.

3. Results

The preliminary and postliminary survey responses were analyzed and measured through the use of a nominal scale, assigning numbers to all possible answers without any rank or priority. Participant demographics are shown in Table 1 and select results of the preliminary and postliminary survey are shown in Tables 2 and 3.

Table 30. Survey Participants

Preliminary				Postliminary			
Male/Female	9	5		Male/Female	9	2	
Faculty/Staff/Student	4	3	7	Faculty/Staff/Student	3	1	7
Grad/Undergrad/Other	3	4	0	Grad/Undergrad/Other	3	4	0

Table 2. Preliminary Survey Results

Do you consider yourself to be environmentally friendly?	Very	Somewhat	Not so much	Not at all
	5	6	2	1
How familiar are you with the term sustainability in regard to a building's operating system?	Very Familiar	Somewhat Familiar	I've Heard of it	Not Familiar
	6	7	1	0
How familiar are you with how much energy the building consumes during a 5 day week?	Very Familiar	Somewhat Familiar	I've Heard of it	Not Familiar
	0	3	2	9

Table 3. Postliminary Survey Results

How many times a day did you view the eco-feedback dashboard?	0	1-3	4-7	7-10	More than 10
	0	7	3	0	1
Did the eco-feedback dashboard help you learn more about the building's energy consumption?	Very	Somewhat	Not So Much	Not at all	
	5	6	0	0	
Was the information on the eco-feedback dashboard easy to understand and comprehend?	Very	Somewhat	Not so much	Not at all	
	4	7	0	0	
Did the eco-feedback dashboard influence you to be more environmentally friendly?	Very	Somewhat	Not so much	Not at all	
	2	5	3	1	

4. Discussion

The study participants appeared fairly knowledgeable in sustainability and resource consumption. Study participants found the display of the eco-feedback dashboard somewhat easy to understand but predominately commented that the

graphics needed to be easier to understand. Participants overwhelmingly responded that providing graphics that were easier to comprehend would attract more viewers to the EFD. This is consistent with what was observed during EFD deployment. Two weeks into the dashboard deployment and after receiving multiple questions regarding how to read and interpret the information on the dashboard, the researchers posted an instructional guide (Figure 3) to assist viewers. The participants reported that their overall understanding of building resource consumption increased while the dashboards were in place. General recommendations for dashboard placement include at elevator landings, student lounges, and other areas that did not impede traffic, such as in hallways. It was observed that building users would touch the dashboard screen, thinking it was touchscreen. The screen was quickly covered in fingerprints as a result. Future deployments could use trackball, touchpad or touchscreen components.

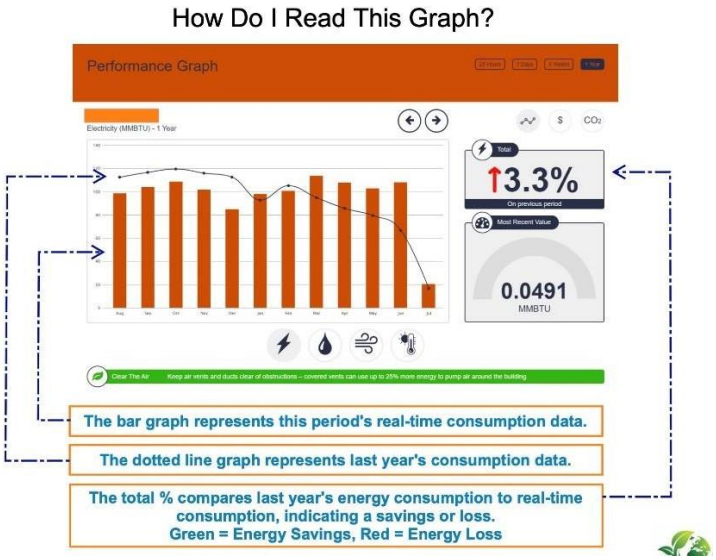

Fig 3. Posted instructions for eco-feedback dashboard

The participants reported that their understanding of building resources and sustainability issues increased as a result of the dashboards. Given the results between the preliminary and postliminary surveys, this strongly suggests that users believe the EFD is educative. Participants also believe that the EFD influenced their behavior regarding resource consumption. Perhaps they were intrigued with the new technology or perhaps they were drawn to its novelty, but either way, the deployment of the EFD did appear to increase awareness around sustainability, building resources and personal consumption. Researchers had access to all consumption data for the period of the study, 1 year prior to study and the after conclusion of study. The EFD's were only deployed for 9 weeks, during Summer semester when enrollment and building use is low. This was further exacerbated by building use limitations created by the COVID-19 global pandemic. Building use the previous year was at record lows due to the pandemic and comparative data is questionable. Researchers further observed that post-occupancy adaptations to building systems design functionality had taken place, bringing to question design-intent versus user-need and how that will be evaluated in future studies.

5. Conclusion

The objective of this research was to assess visual dashboard methods to proactively influence building occupants' perception of energy and water consumption via the implementation of an EFD. The results obtained from both the preliminary and postliminary survey validates the presumption that an EFD installed within the Gorrie Center Building in summer 2021 could both educate and engage building occupants in understanding their energy and water consumption. Although it's proven the EFD attracted and engaged the occupants within the building to some extent, more data is needed to conclude that it is influencing their actual consumption behavior. Therefore, a need for a more developed graphical visualization design is needed to attract, engage, and influence building occupants on energy and water consumption; thus, encouraging overall building consumption savings more proactively.

To further validate and improve upon this research study, there are multiple avenues in which research can be focused. The EFD's design must first be revised to display more comprehendible graphs and tables for the occupants

within the building. Furthering the updated design of the dashboard system, future research should develop a historic baseline consumption graph for the building. After the development of the baseline, researchers can then deploy the revised EFDs and compare the real-time consumption data to the baseline to validate any major changes in building consumption. Through the installation of electrical and HVAC sensors in each classroom and water sensors to each bathroom, researchers can integrate the real-time data obtained from these sensors into an interactive, color-schematic BIM Model highlighting each room's consumption data. Adding this kind of in-depth information to an EFD allows building occupants to further understand which rooms within the building may be responsible for the greatest energy consumption and learn ways to further reduce them.

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