Designing Eco-Feedback to Calculate Carbon Footprint of Ecological Waste

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ARTICLE INFO	ABSTRACT
	Carbon footprint is a measure of the exclusive total amount of carbon dioxide (CO_2) emissions that is direct and indirectly caused by an activity. Carbon footprint is necessary because nowadays, almost all human activities will contribute to carbon emission, especially waste disposal. This paper discusses the feedback of designing an eco-feedback intervention, which is ecoWaste, to deliver feedback on individuals' or groups' behaviors (students of hostel residents) with a goal of reducing environmental impacts as a green campus initiative. Feedback is delivered by automatically sensing activities and feeding related information back through a computerized system. The objectives of this research are to design eco feedback that displays carbon footprint and to visualize information that calculate carbon footprint and motivate people's actions which are to separate ecological waste and recycle. The eco-feedback was designed using an intervention technique that consists of information, comparison, incentive and reward or disincentive and punishment, commitment and feedback. For the evaluation, ten respondents of hostel residents were chosen to evaluate the ecoWaste web application for two weeks. Then the respondents were given questionnaires which consist of two parts which were demographic and behavior questions, and impact of design. From the findings, it is shown that ecoWaste can motivate people and create awareness on the importance of waste separation and by displaying the amount of carbon footprint in each waste, carbon footprint managed to be reduced.

1. Introduction

Eco-feedback technology delivers feedback on individual or community behaviors with a goal of reducing environmental impact [1]. Eco-feedback technology is to increase public lack of awareness and understanding about how their everyday behaviors such as driving to work or showering affect the environment [1]. Froehlich [1] also stated that eco-feedback link to automatically sensing those activities and feed related information back through a computerized system. In this paper, activities that are related to environmental impact is to create awareness among public in recycling and

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separate waste to reduce carbon emission. Developed nations can generate several pounds of solid waste per consumer daily, not only directly in the homes but also in factories that manufacture goods [2]. Ecological waste is a part of solid waste; that can be recycled such as papers, plastic and cans [3]. Basically, there is one way to reduce carbon emission in the atmosphere which is by recycling. Recycling is reprocessing of old materials into new products, with the purposes of avoiding the waste of potentially useful materials or turning it into a usable raw material to make another product [4][9]. People must not only recycle but also need to separate waste before recycling. So, the purpose of this research is to develop or design an eco-feedback technology that will calculate the carbon footprint of ecological waste on campus. This is to create awareness among people about carbon emission in the atmosphere and encourage people to recycle and separate wastes to reduce carbon emission.

2. Related Work

2.1 Environmental Psychology

Environmental psychology is a study of how the environment affects human behaviors and how human behaviors affect the environment [1]. Environmental psychology has a goal of changing people's and society's behaviors to increase the environment sustainability by facilitating responsibility in ecological behaviors and social wellbeing as a new positive social value [5]. To promote pro-environmental behaviors, common intervention techniques were used in environmental psychology. Examples of the intervention techniques are information, comparison, incentives and rewards or disincentives and punishment, commitments or goal-setting and feedback [1].

2.2 Eco-feedback Technology

According to Froehlich [1], eco-feedback technology is "information presented to users about their individual's or group's behaviors, with a goal of influencing future energy saving strategies and reducing environmental impact". Eco-feedback is a technology that motivates and triggers people to think, act, reflect and consume sustainably. Eco-feedback technology is produced based on people who lack awareness and by researching about how their daily behaviors affect the environment. [6] stated that eco-feedback is more efficient when given frequently, presented clearly using computerized tools, and historic or normative comparison are allowed. Normally, eco-feedback is associated with behavior change. Eco-feedback studies have tried to measure behavior change. Eco-feedback also appears as a study on how the environment affects human behavior's and how human behaviors affect the environment [5]. Feedback seems to work because it consists informational and motivational properties. Thus, it provides a basis for assessment and action, and enables progress towards a goal [6]. Table 1 shows the intervention techniques in ecoWaste application that adapted the eco-feedback technology intervention design [1] techniques that either require or can be enhanced by behavioral feedback.

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Table 1
Intervention technique used in ecoWaste intervention

Intervention Technique	Description
Information	The website contains information about carbon footprint, recycling tips and quizzes about the carbon footprint, recycling and etc. It will increase people knowledge about of carbon footprint.
Comparison	Users can compare their carbon footprint from previous weeks. They can check whether the carbon footprint is increasing or decreasing.
Incentives and Rewards	If the residents in the hostel did not achieve the target set by the management, all of the residents will be punished. If they achieve the target or goal they will be rewarded.
Commitments or Goal-setting	The users will feel motivated to separate waste correctly because each bin will calculate carbon footprint for different type of ecological waste.
Feedback	In the form of a graph each type of waste will be represented by a different color that identify the user which type of waste they recycle and contribute to carbon emission mostly.

2.3 Carbon Footprint

Carbon footprint is a measure of the exclusive total amount of carbon dioxide (CO_2) emissions that is direct and indirectly caused by an activity or is accumulated over the life stage of a product [7]. This research will only focus on the calculation for ecological waste such as papers, cans and plastic bottles because one of the objectives of this study is to motivate people to separate their solid waste. The formula to calculate carbon footprint has been adapted from [8].

3. Methodology

The study started by preparing the bins that have weight sensor on each of them. The sensor detected the weight of the ecological waste and calculated the carbon footprint of it. The data collected from the sensor were the weight of each ecological waste that was collected and then the carbon footprint was calculated. Next, it was displayed in the eco- feedback web application. The testing was conducted for two weeks after the development of ecoWaste web application was complete. The test dealt with real users who used the ecoWaste application. Ten participants of the hostel residents at UiTM Perlis were chosen. The questionnaires distributed to them consist of two parts; demographic and behavior questions in the first part and the impact of the ecoWaste towards participants' behaviour in the second part. Figure 1 shows the research design of how the overall research was conducted.
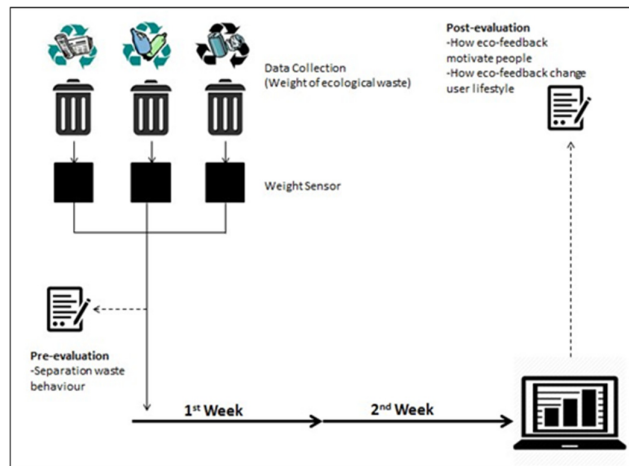
Fig. 1. Research Design

4. Results and Findings

As mentioned earlier, the intervention techniques (Table 1) in the eco-feedback technology design are information, comparison, incentives and rewards or disincentives and punishment, commitments or goal-setting and feedback techniques that either require or can be enhanced by behavioral feedback. In this paper, the feedback intervention technique is discussed. This is one of the most effective techniques which has both informational and motivational properties. It provides a basis for assessment and action, and enables progress towards a goal. In Figure 2, each type of waste was represented by a different color. Blue represents plastics, red represents papers and yellow represents aluminum cans. This page also provides a goal which is of the amount that users need to achieve in the future. The results displayed manage to motivate users to reduce the carbon footprint based on the goal. Feedback is effective when the users can understand the information easily. A graph can convey important and crucial data more vividly than a table because of its shape and color. This is the reason why graph was chosen as a feedback technique in ecoWaste web application.

Fig. 2. Result pages that contain feedback technique

The eco-feedback design evaluation was done on real users to determine whether the web application met the objectives of the project. According to Froehlich [1], to evaluate the eco-feedback display, a survey was conducted on ten participants where they had to update data using ecoWaste application for two weeks.

In the pre-evaluation session, residents' of the hostel resident were approached. Pre- evaluation was conducted to look into the residents' level of knowledge about carbon footprint and their behavior in separating waste. Then, the users were asked to evaluate ecoWaste web application. Post-evaluation was conducted to know the impact of the design on users' behaviour. There are five design implications which consist of: the number of times the data was updated in a day or week, the measurement units or other representations of consumption that are most appropriate to present (e.g., weight in gram (g) and carbon footprint in gram of CO_2 (g/ CO_2), the level of granularity of data (e.g., did users view data from web application easily), the accessibility and medium of the information (e.g., push interface vs. pull interface, or an ambient display vs. web application) and lastly, the ability for users to make comparisons which was self-comparison (past behaviors). From the findings, all respondents agreed that the graph provided in ecoWaste is convenient and can persuade them to reduce carbon footprint. They stated that when data was presented in the form of a graph, it allowed them to visualize clearly factors that contribute to the environment such as total of carbon footprint every week, other hostel residents' contributions and also which waste that was the least or most collected and their total of carbon footprint. This is because a graph can convey important data more effectively. With the data displayed, participants could increase their awareness that any activity they do does contribute to the environmental sustainability, and people's behaviours and lifestyles will lead to carbon emission.

5. Conclusion

ecoWaste is a web application that functions as eco-feedback technology to motivate people to reduce carbon footprint. The main objective of this study is to visualize sensed information that calculate carbon footprint and then motivate peoples' action to separate ecological waste. The strength of the ecoWaste is on the content of the web and the visualization of the carbon footprint in the form of a graph that is displayed in ecoWaste web application that can motivate people's action. In addition, when the calculated footprint is displayed, comparison among groups or individuals can also be viewed. These will increase motivation in changing people's behaviour on how to compete with others in reducing their carbon footprint result. The eco-feedback technology in this research manages to visualize sensed information from the bins attached with weight sensors, then calculates the carbon footprint of each separated waste. Based on the result from the distributed questionnaires, respondents mostly stated that ecoWaste motivated them to reduce carbon footprint and encouraged them to separate waste which will help other parties to recycle easier and at the same time contribute to save the environment.

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