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Abstract:

Acknowledging environmental sustainability as one of the most critical global challenges in our time, information systems (IS) scholars and practitioners have begun to address environmental problems by developing and implementing various green information systems. Besides pro-environmental IT artifacts, we argue that user-oriented green practices play a crucial role in ameliorating the adverse effects that result from making, using, and disposing electronic devices. To that end, we examine user intentions toward engaging in pro-environmental behaviors that can penetrate the electronic device lifecycle, which includes choosing, using, and disposing such devices. In particular, we adopt the extended theory of planned behavior as a lens and suggest ecological beliefs among users can determine their ecological attitude, subjective norms, and perceived behavioral control, which, in turn, can shape their pro-environmental behavior. Also, ecological knowledge appears to play an influential role in changing user intentions to perform pro-environmental practices. We also revisit relevant green IT and green IS literature while providing future research directions.

Keywords: Green IT, Green IS, Pro-environmental User Behavior, Theory of Planned Behavior, Environmental Sustainability

Matthew Jensen was the accepting senior editor for this paper.

1 Introduction

Advances in consumer electronics continue to proliferate throughout our daily lives, and this continual advancement lowers prices and increases performance (Moore, 1965). At the same time, something must be done with the equipment that people and organizations replace, which raises issues concerning ecological efficiency, equity, and effectiveness across the electronic device lifecycle (Dyllick & Hockerts, 2002; Watson et al., 2010, Yang & Kang, 2020). According to the most recent Global E-Waste Monitor report, e-waste (i.e., discarded electronics such as computers, tablets, and smartphones) reached a record 53.6 million metric tonnes across the world in 2019[1] (Forti et al., 2020). However, only 17.4 percent of that e-waste content was formally collected and recycled. We can attribute this number to the insufficient consideration that have countries given to the technology lifecycle's final stage wherein recycling and reclamation occur. In this sense, "the elephant in the junk room" grows ever larger as technology continues ever more fully to integrate into individuals' lives and consumer electronics' lifespan becomes ever shorter.

Companies, governments, and societies have various roles and responsibilities regarding environmental issues (Murugesan, 2008). However, people often underestimate the role that users play in the lifecycle's concluding phases and undermine their motivation to provide supportive input. Environmental organizations and societies should efficiently leverage users' talents and resources through the technology lifecycle to help address the conflict between green growth and economic growth (Sarkis et al., 2013). Unfortunately, users simply seem to not engage in this stage (Forti et al., 2020). Due to their limited individual influence and resources, users generally act as passive performers in green organizational initiatives.

Put differently, users represent the largest interest group in the most significant steps (i.e., purchase, use, and disposal) in the consumer electronics lifecycle. If they choose to consume electronics more pro-environmentally, the accumulated efforts they make will be evident. Similarly, if users choose to circumvent green practices and routinely discard e-waste, they could magnify the adverse effects of e-waste on the environment.

Users gain various insights when interacting with technology, and such "bottom-up" insights (Hedman & Henningsson, 2016) can benefit the many ways in which information technology vendors, e-waste disposers, and governmental entities solve e-waste issues. As an example, one insight might regard where and how to choose and purchase environment-friendly devices (green purchase), whereas another might contribute to innovative power management functions on computers and smartphones (green use). Users can also identify and share locations to recycle discarded electronics (green disposal). In sum, user experience, knowledge, and sense-making can smoothly bolster ecological efficiency and effectiveness initiatives (Dyllick & Hockerts, 2002; Hedman & Henningsson, 2016; Seidel et al., 2018; Watson et al., 2010).

Thus far, information systems (IS) research has dealt with relatively fragmented green practices (green purchase, green use, or green disposal). However, we lack research on holistic pro-environmental user behaviors in the electronic device lifecycle. For example, research on green purchase behavior and green consumerism topics have flourished in the marketing and consumer behavior literature (Carrington et al., 2010; Cheung & To, 2019; Han & Kim, 2010; Kim & Chung, 2011; Kim et al., 2013; Moisander, 2007; Zaremohzzabieh et al., 2020). In the IS field, research primarily focuses on organizational green IS, with an emphasis on the motivations and outcomes of green IT adoption and dissemination (Bose & Luo, 2011; Chen et al., 2011; Molla & Abareshi, 2012; Loeser et al., 2017; Molla et al., 2014, Singh & Sahu, 2020). Green disposal studies widely appear in the ecology literature and focus mostly on growing e-waste problems (e.g., Arain et al., 2020; Echegaray & Hansstein, 2017; Islam et al., 2021; Shevchenko et al., 2019; Wang et al., 2011).

Hence, in this study, we explore systematic pro-environmental behaviors in parallel with the electronic device lifecycle. We also consider how numerous electronics users choose, purchase, use, and dispose of devices. While one can identify some empirical pro-environmental behavioral studies in the literature (Koo et al., 2015; Yoon, 2018), most seem to take a more conceptual approach (Boudreau et al., 2008; Dedrick, 2010; Sarkis et al., 2013; Watson et al., 2010). Therefore, to fill the gap in empirical studies, we conduct an in-depth investigation into pro-environmental user behavior while explicating its underlying planning mechanism.

Specifically, we address two main research questions:

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[1] The Waste Electronic and Electrical Equipment (WEEE) Forum (2021) estimated e-waste to amount to 57.4 million tons in 2021.

RQ1: What pro-environmental behavior do users perform in the consumer electronic device lifecycle?

RQ2: How and why do users engage in pro-environmental behavior?

2 Literature Review and Hypotheses Development

2.1 Green IT, Green IS, and Pro-environmental User Behavior

While studies in the literature have often used the terms “green information technology” (green IT) and “green information systems” (green IS)” interchangeably, they have conceptual differences. Green IT rests on the assumption that technology itself is the source of and the solution to environmental problems such as carbon emission and e-waste (Murugesan, 2008; Yang et al., 2020). In contrast, green IS acknowledges the significant role that users have in the electronic device lifecycle. Green IS proponents suggest that a pro-environmental information system, which includes the people and procedures that organize them, can better solve environmental problems than simple technological solutions (Davenport & Linder, 1994; Dedrick, 2010; Silver et al., 1995). Researchers have conceptualized green IS, which subsumes both technological and human components, in various literature ways. Murugesan (2008), for example, characterized practices to design, manufacture, use, and dispose of computers and peripherals with minimal or no impact on the environment in an effective and efficient manner. Watson et al. (2010), early thought leaders on the topic, stressed the role that user beliefs in ecological efficiency, equity, and effectiveness play in green IS. Our work embraces both the practical and ideological meanings behind green IS since end users (i.e., our unit of analysis) can engage in many pro-environmental practices based on diverse ecological beliefs and values. Therefore, we define pro-environmental user behavior (PUB) as:

> *Individual choices and actions, based on one’s belief in eco-efficiency, effectiveness, and equity, that aim to minimize one’s negative impact on the environment and promote sustainability while purchasing, using, or disposing of electronic devices and parts.*

Following Dedrick’s (2010) conceptualization, we propose that users participate in three critical steps in electronic devices’ lifespan: green purchase, green use, and green disposal (see Figure 2). Research on these lifecycle steps predominantly come from three different disciplines that focus on one step each.

First, green purchase has attracted the most research attention in the green marketing and purchase behavior literature. Indeed, green consumerism provides a comprehensive theoretical framework that illustrates an ethical consumer attitude toward protecting the natural environment (Carrington et al., 2010; Emekci, 2019; Moisander, 2007; Trivedi, 2019). Relevant studies focus on factors that include consumers’ ecological concerns, ecological awareness, and purchasing preferences for ecologically friendly products and services (Kim & Chung, 2011; Nimse et al., 2007; Yadav & Pathak, 2017). Studies have also explained consumer preference for patronizing ecologically conscious organizations and entities (Han & Kim, 2010; Kim et al., 2013).

Second, green IT adoption and dissemination has attracted the most research attention in the IS literature. Many studies have explored the antecedents and consequences of green IT adoption and dissemination in organizational settings (Bose & Luo, 2011; Chen et al., 2011; Deng & Ji, 2015; Molla et al., 2014; Thomas et al., 2016). The IS literature has also touched on pro-environmental IT practice and user engagement (Chow & Chen, 2009; Molla et al., 2014).

Third, green disposal (which corresponds to the technology lifecycle’s final stage) has attracted the most research attention in the environmental psychology literature, which has frequently focused on clean manufacturing and corporate operations (Chi et al., 2014; Echegaray & Hansstein, 2017; Saphores et al., 2012; Wang et al., 2011). Given the pro-environmental behaviors associated with various phases of the electronic lifecycle, we argue that users can embrace diverse roles in this process (i.e., mindful consumers (green purchase) or active environmentalists (green disposal)).

2.2 An Extended Theory of Planned Behavior in the Green IS Context

Given the planning and motivation mechanisms in pro-environmental behavior across the electronics lifecycle, we leverage the theory of planned behavior to gain research insights. Green consumer behavior research has widely applied the theory to identify antecedents of green purchase intentions (Ha & Janda, 2012; Kim et al., 2013; Paul et al., 2016; Yadav & Pathak, 2016).

Ajzen (1985) developed the theory of planned behavior (TPB) based on the theory of reasoned action (TRA) (Fishbein & Ajzen, 1977). TPB corrected a flaw in TRA by dealing with significant confounding risks between attitudes toward the decision object and the influence of subjective norms in the decision calculus (Ajzen, 1985).TPB also incorporates perceived behavioral control, a non-volitional factor. With respect to pro-environmental behaviors, there are external constraints such as limited resources (e.g., affordability of green electronics at a higher price), the cost of time and effort (e.g., reusing and recycling electronics rather than merely discarding them), and pertinent environmental factors such as recycling facilities' availability and location. Hence, we found the TPB to have advantages over other similar frameworks (i.e., TRA).

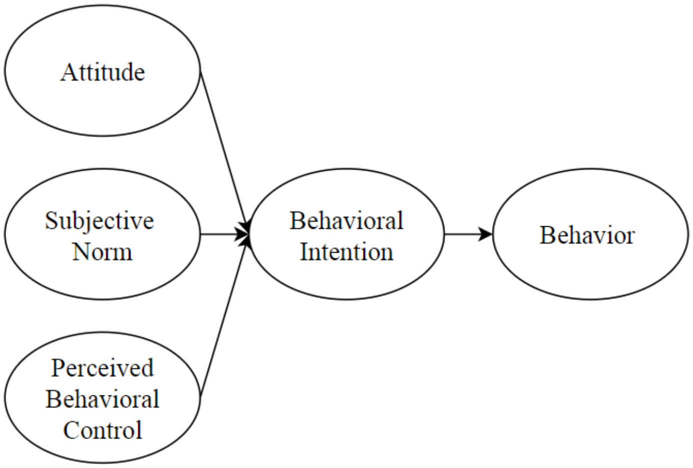


Figure 1. Theory of Planned Behavior (TPB) (Adopted from Ajzen, 1991)

According to the TPB, attitude, subjective norms, and perceived behavioral control come together to shape individual behavioral intentions and behaviors toward decisions (see Figure 1). Attitude refers to "the degree to which a person has a favorable or unfavorable evaluation of the behavior in question" (Ajzen, 1985). Ecological attitude, which refers to how users judge pro-environmental practices, determines if they will engage in environmentally friendly practices. Ramayah et al. (2010) also suggest the need to consider linkages between perceived consequences and intended behavior. Paul et al. (2016), however, note that attitude represents the main factor that predicts green purchase intention. Likewise, we propose that:

H1: Ecological attitude is positively associated with the intention to engage in pro-environmental user behavior.

In the TPB framework, subjective norms about the worth of a specific activity determine subsequent behavioral intention to engage in such activity. Subjective norms can be interpreted as the perceived social pressure to perform a given behavior or not (Ajzen, 1985). Social influences can come from family, friends, colleagues, and other closely related social members. Subjective norms capture how one perceives the social pressures associated with any given pro-environmental behavior. Essential norms can both overtly and covertly influence individual green behavioral intentions. For example, one may easily follow family or friends' suggestions to choose an energy-saving computer or identify an electronic device with pro-environmental features and functionalities. Clearly, subjective norms impact purchase decisions, but they also impact disposal decisions if one wants to be a part of a community or micro-society that favors pro-environmental practices. Therefore, we hypothesize:

H2: Subjective norms are positively associated with the intention to engage in pro-environmental user behavior.

Another salient factor in TPB concerns users' perceived behavioral control. Perceived behavioral control refers to the extent to which users perceive performing a given behavior as easy or difficult (Ajzen, 1985). According to Ajzen (1989), perceived behavioral control represents the ability to use resources, which implies facilitating factors and action control (Triandis, 1977). Comparing attitude and subjective norms with internal factors, we see that perceived behavioral control revolves mainly around external influence. Indeed, as we note above, users have to overcome environmental constraints while participating in pro-environmental practices. Hence, we propose that:

H3: Perceived behavioral control is positively associated with the intention to engage in pro-environmental user behavior.

As we bridge the TPB with the ecological belief concept in the green IS literature, we look at the different sorts of external factors that play a role in pro-environmental behavioral planning. Fishbein and Ajzen (1977) suggested that external beliefs in three different categories (attitudinal, normative, and control) constitute the antecedents to attitude, subjective norm, and perceived behavioral control, respectively. Drawing from Coleman's (1986) micro-macro model that proposes how organizational and social sustainability contexts influence organizational and individual beliefs about the environment and sustainable activities, Melville (2010) conceptualized the TPB belief-action-outcome framework in an IS context. This framework postulates that social and organizational structures can impact individual beliefs about the environment, which, in turn, can be interpreted (reflected or realized) through user engagement in sustainable actions and eventual environmental and economic outcomes. More specifically, Watson et al. (2010) classified two ecological beliefs: ecological efficiency and ecological equity. Based on their research, ecological efficiency relates to delivering competitive-priced goods and services that satisfy human needs while progressively reducing adverse ecological effects in line with the earth's carrying capacity (DeSimone & Popoff, 1977). Ecological equity refers to "equity between peoples and generations and particularly the equal rights of all peoples to environmental resources (Gray & Bebbington, 2000).

Taken together, these conceptual green IS studies direct our conjecture about the relationships between ecological beliefs and three perceived behavioral control antecedents to the intention to engage in pro-environmental user behavior. The ecological beliefs will likely shape people's attitudes toward green IT practices, promote norms and cultures that support pro-environmental activities, and increase their perceived behavioral control when facing problems that can hinder their green behavior intention. Thus, we hypothesize:

H4a: Ecological beliefs are positively associated with ecological attitudes.

H4b: Ecological beliefs are positively associated with subjective norms about green IS.

H4c: Ecological beliefs are positively associated with the perceived behavioral control over green IS.

Also, Chan and Lau (2002) define environmental knowledge as how an individual understands environmental issues. Fryxell and Lo (2003) further define environmental knowledge as how people understand the environment, their relationships with environmental impact, and their responsibility for sustainable development. Mostafa (2007) build on Fryxell and Lo's (2003) definition and accentuate knowledge about core relationships that may exert influence on environmental surroundings. When people care about environmental issues, their attitude can influence their intention to behave pro-environmentally (Scott & Vigar-Ellis, 2014; Yadav & Pathak, 2016). In the green IS context, users' ecological attitude can encourage them to investigate ecological information and knowledge and foster their intention to engage in pro-environmental behaviors. Thus, we hypothesize:

H5a: Ecological attitude is positively associated with ecological knowledge.

H5b: Ecological knowledge is positively associated with the intention to engage in pro-environmental user behavior.

3 Research Methodology

3.1 Qualitative Inquiry with Focus Groups

In this study, we operationalized the constructs and measurement items by conducting focus groups with general electronics users and adopting measures from relevant literature. This study differs from prior studies in that we integrate fragmented pro-environmental user behavior (i.e., green purchase, green use, and green disposal) into the broader electronic devices lifecycle context (Forti et al., 2020). As Figure 2 shows, users can act as green consumers, green users, and even green volunteers while contributing to various electronics lifecycle phases, such as design and manufacture, marketing and sales, purchase and use, and recycling and disposal.

To confirm our conjecture and evaluate the measurement items, we initiated a qualitative inquiry into pro-environmental behavior with 11 focus groups and 41 participants in total (more specifically, they comprised business/information systems/computer science faculty and students from a southeastern university in the US). We adopted a semi-structured discussion approach because, with it, we could explore our research question with every participant in depth and obtain novel insights from discussing follow-up questions and pertinent topics (Adams, 2015). Our initial and follow-up interview questions revolved around 1) life examples about pro-environmental behaviors, 2) ecological knowledge and beliefs (rarely empirically examined in the IS literature), and 3) motivational mechanisms for pro-environmental user behavior.

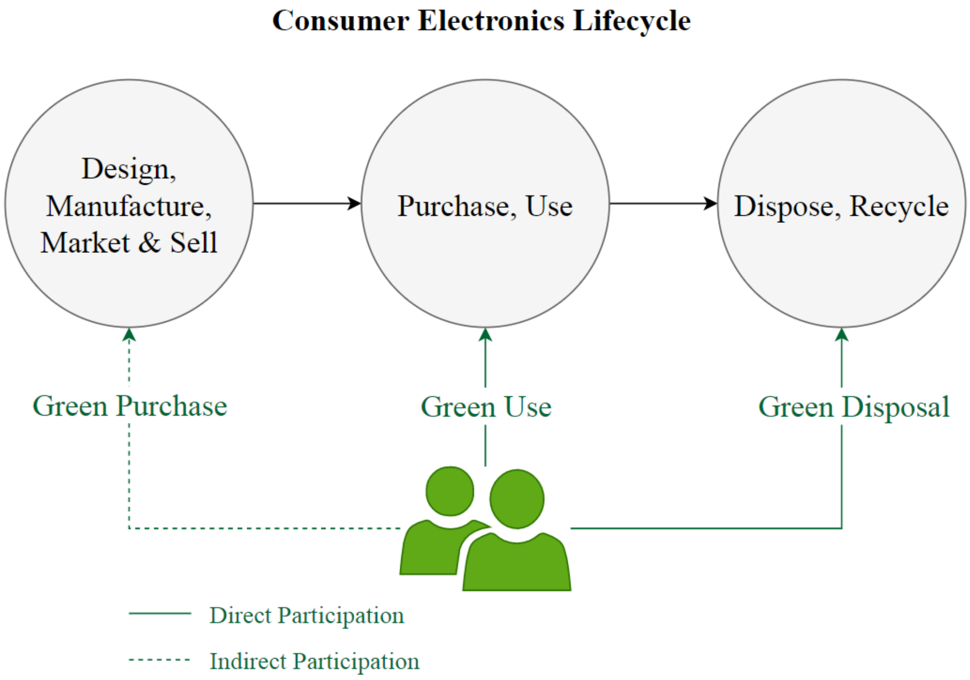


Figure 2. Pro-environmental User Behavior in the Consumer Electronics Lifecycle

As Table 1 shows, we identified categories from the focus group meeting minutes, additional comments from the participants, and our field notes. Most comments and viewpoints from this examination concur with the green IT/IS literature and our hypothetical expectations. When illustrating pro-environmental behaviors regarding the consumer electronic lifecycle, participants most frequently mentioned reusing and recycling devices and parts (66%), enabling energy-saving functions in using IT (37%), and using pro-environmental technologies (24%). While discussing the motivational mechanism for why they engaged in pro-environmental user behavior, most participants noted protecting the environment and preserving resources as imperative (76%). Also, 39 percent of the participants' comments referred to ecological equity and 37% to ecological efficiency and ecological effectiveness. Further, they ranked convenience (49%) first in determining users' intention to participate in pro-environmental behavior followed by ecological knowledge and ecological awareness (34%), platforms and channels (27%), and others. Simultaneously, a few novel ideas and items emerged in the focus group discussions. For example, IT-savvy participants (e.g., computer science faculty and students) had significant interest in discussing technological solutions, such as cloud computing services, server visualization, and energy-efficient data centers. Moreover, it appears that most IT-savvy participants supported green engineering in designing and using pro-environmental products and processes (U.S. Environmental Protection Agency, 2021). Intriguingly, most business faculty and student participants preferred utility topics, such as pro-environmental practices' costs and benefits. However, participants collectively expressed their ecological beliefs and an interest in performing more roles and responsibilities in protecting the environment and preserving various resources.

Table 1. Focus Group Data Analysis Results

Themes (interview questions)	Categories (concepts)	Freq. (%)
Pro-environmental user behaviors (e.g., could you give us some examples of pro-environmental IT practices you have done in your daily life?)	• Reusing and recycling old devices and parts	27 (66%)
	• Reducing power consumption (turning off digital devices and peripherals, such as PCs and smartphones; using energy-saving modes when devices are not in use)	15 (37%)
	• Using green IT (cloud computing services, server visualization, energy-efficient data centers)	10 (24%)

Table 1. Focus Group Data Analysis Results

	• Purchasing green electronics (choosing energy-efficiency electronics, choosing products made by resource-renewable materials)	9 (22%)
	• Supporting green design and manufacturing (participating in pro-environmental product design and activities)	8 (20%)
	• Sharing digital services and resources (using public computers in schools and libraries)	7 (17%)
Reasons why pro-environmental user behaviors are important (e.g., Could you tell us why pro-environmental user behaviors are important?)	• Protecting the environment & preserving resources (protecting the earth, ocean, wildlife, etc.; reducing e-waste, toxic chemicals, greenhouse gases, etc.)	31 (76%)
	• Performing roles and responsibilities and setting a good example for future generations (environmental ethics, ecological beliefs)	16 (39%)
	• Achieving economic efficiency (promoting a lower overall power usage, reducing costs, and increasing companies' profits)	15 (37%)
	• Protecting people's health	7 (17%)
Factors that promote or hinder pro-environmental user behavior (e.g., Could you share with us what factors will influence pro-environmental behaviors?)	• Convenience and ease of doing (making pro-environmental activities easy to do)	20 (49%)
	• Ecological knowledge and ecological awareness (lacking relevant environmental knowledge and awareness, providing pro-environmental information about how to practice)	14 (34%)
	• Platforms and channels (used devices trade-in/donation platforms, recycling centers)	11 (27%)
	• Companies' roles and responsibilities (developing green electronics, power consumption, and e-waste recycling)	10 (27%)
	• Governments' roles and responsibilities (sales tax on green products; environmental tax incentives)	9 (22%)
	• Individual financial incentives or concerns (extra costs for the green features and functionalities of electronics; most of them are expensive)	9 (22%)
	• Advances in green technologies (green functions of electronics, green efficiency)	7(17%)

3.2 Survey Setting and Participants

Following the qualitative inquiry, we collected quantitative data through a field survey from five American universities that varied in size (approximately 7,000 to 30,000 students) and background (e.g., teaching vs. research). Since college faculty and students generally have access to computers and similar electronic devices, we believe this sample fits our goal to examine users' intention to engage in pro-environmental behaviors through the electronics' lifecycle. The participants predominantly included undergraduate and graduate college students who participated in exchange for extra course credit. We illustrate their demographic and IT-relevant descriptive statistics in Table 2. We received 394 responses in total. After we rigorously screened them (e.g., removed inattentive and incomplete responses and extreme outliers), 247 valid responses remained (DeSimone et al., 2015). To ensure response bias did not pose a concern, we conducted individual t-tests on the means of main constructs by examining the first and last 50 respondents. The results indicated that respondent bias had a minimal impact on our results (see Appendices B and C).

Table 2. Respondent Demographics

Gender	Male	112 (45.34%)	**IT use experience (years)**	Range	2-40
	Female	135 (54.66%)		Mean	12.35
	Total	247 (100%)		Std. dev.	5.81
Age	20 and below	110(41.53%)	**Replacement frequency**	Range	0-10
	21-30	115(46.56%)		Mean	4.60

Table 2. Respondent Demographics

	31-40	16(6.48%)	**(years)**	Std. dev.	1.60
	41 and above	6(2.43%)	**IT proficiency**	Fundamental	50 (20.24%)
Education	Some college credits	153 (61.94%)		Novice	64 (25.91%)
	Associate degree	34(13.77%)		Intermediate	107 (43.32%)
	Bachelor's degree:	48(19.43%)		Advanced	25 (10.12%)
	Master's degree	8(3.24%)		Expert	1 (0.40%)
	Doctorate	4(1.62%)			
Work experience (years)	Range	0-40			
	Mean	4.86			
	Std. dev.	6.15			

3.3 Measurement Development

We adapted the measurement items from key studies in our literature review and focus group discussions. We performed a preliminary analysis to assess basic psychometric properties and retain the most reliable measures for fitting the hypothesized model. In this study, we considered six constructs: ecological belief (seven indicators), ecological attitude (five indicators), subjective norm (three indicators), ecological knowledge (seven indicators), perceived behavioral control (five indicators), and intention to engage in pro-environmental user behavior (seven indicators) (see Appendix A).

3.4 Exploratory Factor Analysis

We conducted an exploratory factor analysis (EFA) to explore the factor structure of constructs while reducing cross-loading items. We applied principal component analysis with varimax rotation to identify variables highly associated with the model's constructs. Through the factor analysis, we identified 34 items with factor loadings above the threshold value of 0.4. Table 3 illustrates an excessive degree of consistency among the items under each factor with their respective factor loadings. After completing the factor analysis, we retained 29 measurement items for further use in the study, and we retained the factor scores obtained from the analysis for hypothesis testing purposes. In our study, ecological belief and ecological knowledge constituted exogenous constructs, while various assessments of subsequent intentions to perform pro-environmental user behavior constituted endogenous constructs.

Table 3. Finalized Indicator Loadings

	Component						
	1	2	3	4	5	6	7
Ecological belief	0.831	0.819	0.770	0.722	0.712	0.648	0.593
Ecological attitude	0.724	0.678	0.646	0.627	0.607		
Subjective norm	0.799	0.769	0.710				
Perceived control	0.855	0.802	0.547				
Ecological knowledge	0.822	0.805	0.726	0.587	0.443		
PUB intention	0.800	0.780	0.694	0.691	0.651	0.587	

3.5 Reliability and Validity

Structural equational modeling studies primarily focus on reliability and validity (Hair et al., 2006). According to Nunnally (1994), reliability levels beyond 0.7 form a threshold to ensure that results reasonably lack measurement error and perform in a reliable manner. In our analysis (Table 4), construct reliability scores across the overall study exceeded 0.7. However, we also assessed reliability in investigating the trait validity features of convergence and discrimination in our construct-validation process (Boudreau et al., 2008; Henseler et al., 2015; MacKenzie et al., 2011). Table 4 shows that the model fit the data well as all the composite reliability scores on constructs and Cronbach's alphas scores for individual scales exceeded 0.7. Furthermore, the average variances extracted (AVE) values exceeded the square of the individual correlations among constructs. Therefore, we obtain sound evidence supporting convergent and discriminant validity among the reflective constructs in the model.

We carefully examined our survey instrument and its administration following guidance from Burton-Jones (2009) and concluded that our study neither suffered knowledge nor rate bias. Specifically, we minimized the likelihood of social desirability or respondent acquiescence bias by ensuring anonymity to the respondents, requesting that they answer each question as honestly as possible, and using intention as a proxy for behavior (Kwak et al., 2019).

Also, we assessed common method bias through two popular tests. First, we performed Harman's (1976) single-factor test. The first factor explained 36.96 percent of the variance (less than 50% threshold), which indicates that no single factor contributed to the majority of the variance (Podsakoff et al., 2003). Second, we employed a full collinearity assessment approach for PLS-based SEM (Hair et al., 2006; Kock, 2015). We placed each construct as the outcome variable to test the variation inflation factor (VIF), and all the VIF values obtained (ranging from 1.4 to 2.5) did not exceed the threshold value of 3.3. Hence, we conclude that common method bias did not pose a significant concern in this study.

Table 4. Construct Reliability and Validity

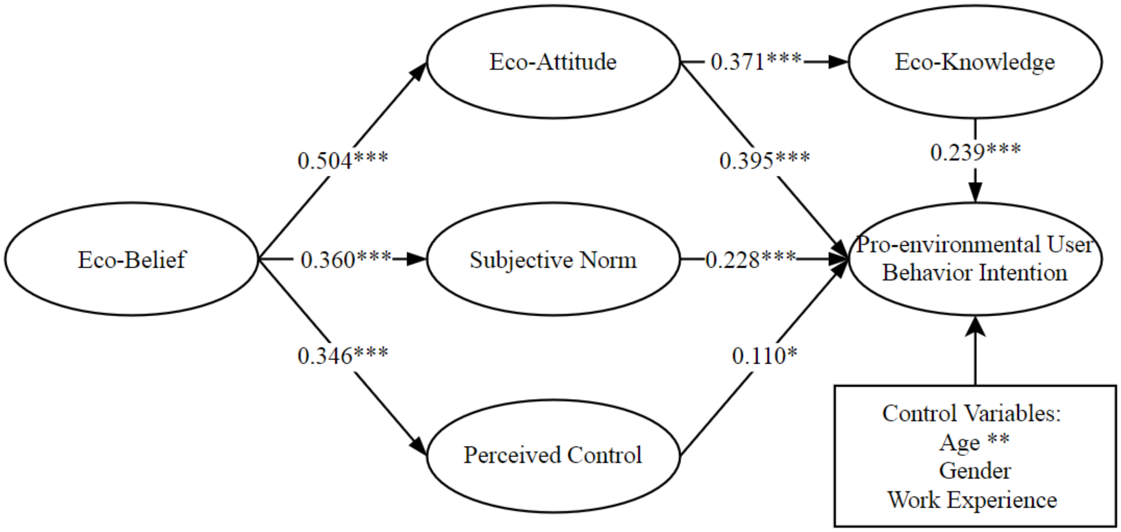
Component	Composite reliability	Cronbach's alpha	AVE
Ecological belief	0.910	0.885	0.593
Ecological attitude	0.889	0.844	0.617
Subjective norm	0.931	0.888	0.819
Perceived control	0.871	0.777	0.693
Ecological knowledge	0.875	0.817	0.591
PUB intention	0.937	0.918	0.711

4 Analysis and Results

4.1 Structural Model

In this study, we used the PLS-SEM to assess the path model due to its advantages in making theoretical predictions with complex models (Hair et al., 2006). We also implemented a standard bootstrap resampling procedure (5,000 samples) to test path significance. We examined the path coefficients using a one-tailed t-test and included age, gender, and work experience as control variables. As shown in Figure 3, we found significant effects that supported the hypothesized expectations for all paths.

As for the antecedents to pro-environmental user behavior, we found positive and significant relationships for H1, H2, and H3, which we developed based on the theory of planned behavior (Table 5). In other words, ecological attitudes, subjective norms, and perceived behavioral control determined user intentions to engage in pro-environmental behaviors such as green purchase, green use, and green disposal to a good extent. We also found support for the hypotheses related to ecological belief and its three antecedents. The evidence corroborates our propositions adapted from seminal theoretical works that DeSimone and Popoff (1977), Gray and Bebbington (2000), Melville (2010), and Watson et al. (2010) conducted. We also found significant and positive relationships between ecological attitude and ecological knowledge and the subsequent intention to perform pro-environmental user behavior in the critical steps in the electronics lifecycle process. To wit, ecological knowledge mediated the path between ecological attitude and the intention to engage in pro-environmental user behavior. However, green knowledge and information may not determine a user's pro-environmental attitude—a stable mental and neural state. In contrast, users with strong ecological attitudes may actively acquire ecological knowledge and behave pro-environmentally given that attitude includes cognitive, affective, and conative (or behavioral) dimensions (Ajzen, 1993; Erwin, 2001). Due to the dynamic and reciprocal relationships between knowledge, attitude, and behavior (Schrader & Lawless, 2004), we conducted a multi-group analysis to explore possible outcomes among various user groups, which we discuss in Section 4.2.



* p < 0.1; ** p < 0.05, *** p < 0.0

Figure 3. Structural Model of Pro-environmental User Behavior in the Electronics Lifecycle

Table 5. Hypotheses Analysis Results

	Result	Original sample	Sample mean	Std. dev.	T stat.	P value
H1: Ecological attitude → PUB intention	Supported	0.395	0.393	0.059	6.703	0.000
H2: Ecological norm → PUB intention	Supported	0.228	0.224	0.061	3.758	0.000
H3: Perceived control → PUB Intention	Supported	0.110	0.114	0.060	1.821	0.069
H4a: Ecological belief → ecological attitude	Supported	0.504	0.513	0.080	6.325	0.000
H4b: Ecological belief → Ecological norm	Supported	0.360	0.370	0.087	4.148	0.000
H4c: Ecological belief → perceived control	Supported	0.346	0.356	0.069	5.017	0.000
H5a: Ecological attitude → ecological knowledge	Supported	0.371	0.377	0.062	6.020	0.000
H5b: Ecological knowledge → PUB intention	Supported	0.239	0.244	0.058	4.161	0.000

4.2 Multigroup Analyses

We examined the influence that user characteristics had on the planning and motivational mechanisms behind pro-environmental user behavior. To conduct our multiple group analyses, we relied on IT proficiency, IT use experience, and electronic device replacement frequency. As Table 6 shows, we found the paths from ecological knowledge and perceived control to pro-environmental behavior intentions to be insignificant among experienced IT users contrary to novice users. Interestingly, paths started with ecological belief were more significant (in terms of significance levels) for more-experienced users than less-experienced users. This result suggests that ecological knowledge and control do not constitute factors that significantly drive seasoned electronics users to engage in pro-environmental behaviors, whereas intrinsic factors such as ecological belief can affect seasoned IT users who may have mastered adequate pro-environmental knowledge and information. For example, ecological belief can be a more critical and direct driver for a user who knows how to enable computer power-saving functions and where to recycle discarded electronics.

In contrast, ecological knowledge and perceived environmental control can concern beginners and affect their intention to engage in pro-environmental activities. Indeed, novice users will likely withdraw from pro-environmental behaviors if they lack the information to choose and purchase an environmentally friendly product, turn on the power saver mode in computers, or locate electronics recycling centers. Likewise, perceived control has little effect on techno-savvy users' (advanced and expert electronics users) intention to engage in pro-environmental behavior compared to fundamental and novice users. Unlike users who replace electronics frequently, perceived behavioral control may not influence users who rarely or seldom replace their electronic devices while they engage in pro-environmental behavior.

Table 6. Multigroup Analyses Results

	P values					
	IT Exp_H	IT Exp_L	IT Prof_H	IT Prof_L	Replace Freq_H	Replace Freq_L
Ecological attitude → PUB intention	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Ecological knowledge → PUB intention	0.545	**0.000**	**0.051**	**0.000**	**0.004**	**0.011**
Perceived control → PUB intention	0.737	**0.015**	0.265	0.145	**0.004**	0.980
Ecological norm → PUB intention	**0.006**	**0.006**	**0.000**	**0.787**	**0.010**	**0.035**
Ecological belief → ecological attitude	**0.000**	**0.000**	**0.000**	**0.001**	**0.000**	**0.000**
Ecological belief → ecological norm	**0.000**	**0.011**	**0.000**	**0.066**	0.101	**0.000**
Ecological belief → perceived control	**0.000**	**0.001**	**0.000**	**0.006**	**0.023**	**0.000**
Ecological attitude → ecological knowledge	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.000**

IT Exp_H: high level of IT use experience > = 12.35 years (mean)
IT Exp_L: low level of IT use experience < 12.35 years (mean)
IT Prof_H: high level of IT proficiency – intermediate, advanced, expert users
IT Prof_L: low level of IT proficiency – fundamental and novice users
Replace Freq_H: high frequency of digital device replacement < 4.6 years (mean)
Replace Freq_L: low frequency of digital device replacement > = 4.6 years (mean)

4.3 Robustness Tests

We conducted two tests to ensure we obtained robust analysis results. First, we tested the research model through the bootstrap resampling procedure with different sample sizes (6,000 and 7,000 samples, respectively). The bootstrapping results concurred with the original model results (see Appendix D). Next, we used an alternative model to examine the original model's robustness (see Appendix E). Specially, we examined the potential linkage between ecological belief and intention to engage in pro-environmental behavior ($\beta = 0.021$, $t = 0.383$, $p = 0.701$) and found that the additional path lacked significance. Thus, we verified the theoretical model's robustness. Further, we performed the bootstrapping procedure 6,000 times and obtained consistent results for the multi-group analysis (see Appendix F).

5 Discussion

Our results suggest that ecological attitude, subjective norms, perceived behavioral control, and ecological knowledge can predict end users' intentions to perform pro-environmental behaviors and ecological knowledge. Also, we found that ecological beliefs play a significant role in determining ecological attitude, subjective norms, and perceived behavioral control.

5.1 Contribution

This study makes multiple contributions to green IS research and practice. First, our research extends the theoretical landscape of green IS, in the aspects of participants, participation sphere, and motivational mechanisms. Unlike previous studies that have focused mainly on IT professionals in the workplace, our study accentuates general users' multiple roles in engaging in pro-environmental behavior parallel to the critical steps in the consumer electronics lifecycle. Hence, the holistic perspective that we propose and apply can mitigate theoretical reductionism, inconsistencies, and conflicting results in previous research. We used an extended theory of planned behavior as a lens and found results that reaffirm prior findings while extending green IS's boundaries beyond green choice and purchase (marketing), green adoption and use (information systems), and green disposal (ecology) to a broader scope that involves user-oriented pro-environmental behavior.

Second, our research inquiry constitutes an empirical contribution in that we developed items to measure pro-environmental user behavior and validated valuable propositions and constructs in previous conceptual work (Dedrick, 2010; Melville, 2010; Murugesan, 2008; Watson et al., 2010) using both qualitative and quantitative data. In particular, we operationalized and examined the ecological belief construct based on the ecological efficiency and ecological equity concepts (Watson et al., 2010) and the pro-environmental user behavior construct based on the electronics lifecycle (Murugesan, 2008) and our in-depth qualitative investigation. Also, our empirical results shed light on the important relationships between ecological knowledge, IT proficiency, and users' intention to engage in pro-environmental behavior.

Our significant results that support the planning mechanisms for pro-environmental behavior also corroborate our conjecture about the potential and possibility for users to address practical environmental problems. Users should be encouraged by environmental organizations and societies to actively participate in pro-environmental behaviors through their daily lives intertwined with the consumer electronic lifecycle. In addition to the artifact-centered green IS (Corbett, 2013; Fridgen et al., 2016; Marett et al., 2013; Recker, 2016), we argue that user-oriented pro-environmental practices, a bottom-up and trivial-to-tremendous alternative, can also be an efficient behavioral solution for environmental sustainability challenges (Gholami et al., 2016).

5.2 Limitations and Implications

Like most studies, our study has several limitations that provide possible opportunities for future research. First, our study has limited potential generality since we used a convenience sample that comprised students and faculty. Such participants typically possess a good education and knowledge and are more prone to socially desirable responses (Kaiser et al., 2008). With that said, we applied various methods to mitigate the effect that it had on our results. Furthermore, one could consider self-selection bias a threat if respondents were mainly pro-environmentalists. As such, future studies may focus more on identifying broader and general samples and on including more diverse participants.

We also need to consider that the ecological belief construct could be multi-dimensional. As Watson et al. (2010) have suggested ecological effectiveness can contain ecological efficiency and equity. While our factor analysis indicates a strong interrelation between the two, the topic requires further investigation. Here, we strictly followed the theory of planned behavior's conventional explications and, in doing so, used many existing conventional measurement items. Even if our analysis successfully supports the assertion that planning mechanisms direct end users' pro-environmental behaviors, we recognize the dangers that a reductionistic perspective may pose and avoid alternative explanations beyond those that our results support.

We consider that in-depth qualitative studies with diverse participants can unveil new ways to understand pro-environmental practices that intertwine with the electronics lifecycle. In particular, focus group participants discussed the design/manufacturing stage in the lifecycle as the green engineering topic emerged. However, our user model does not represent it due to participants' (mainly consumers rather than factory employees) limited experience and knowledge about the design and manufacturing phase in the electronics lifecycle. Hence, researchers could explore that area in the future by conducting field studies with electronics manufacturers and recycling companies. More importantly, researchers could find emerging concepts and theories and, thus, expand green IS research boundaries.

Despite the opportunities for future research, we believe that our work has clear practical implications. First, the planning mechanism we examined can promote pro-environmental user behavior in various settings that range from the workplace to social spaces. Based on the multi-group analysis results, environmental organizations and societies need to educate end users with adequate ecological knowledge, particularly for novice users. Also, they need to cultivate and grow ecological beliefs to promote users' pro-environmental behaviors regardless of their experience and proficiency in using electronic devices.

6 Conclusion

IT-relevant environmental and sustainability issues cause increasing concerns and challenges to many people and organizations. We largely lack an efficient manner to address these "trivial" but important green problems, such as consuming short-lifespan electronics and randomly discarding e-waste. To that end, we articulate the essential role that general users play in the electronics lifecycle based on the general principle that the actors who participate in creating problems with green IS can also contribute to its solutions. By examining these perceptions and the well-established theory of planned behavior, we suggest that ecological belief and ecological knowledge encourage individuals to engage in pro-environmental behavior in purchasing, using, and disposing electronic devices.

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Appendix A

Table A1. Constructs and Measurement Items

Constructs and measurement items	References*
Ecological belief	

Table A1. Constructs and Measurement Items

EB1: I believe that pro-environmental user behavior contributes to the efficient use of environmental resources. (N)* EB2: I believe that reducing energy consumption by digital devices minimizes greenhouse gas emissions. EB3: I believe that pro-environmental user behavior benefits limited environmental resources. (N) EB4: I believe pro-environmental user behavior reduces adverse ecological effects. EB5: I believe that pro-environmental user behavior promotes the fair distribution of environmental resources among all peoples. (N) EB6: I believe that pro-environmental user behavior promotes fair distribution of environmental resources across generations. (N) EB7: I believe that pro-environmental user behavior conserves the resources for everyone. (N)	DeSimone et al. (1997), Molla et al. (2014), McCarty & Shrum (1994), Murugesan (2008), Watson et al. (2010)
Attitude toward pro-environmental user behavior	Molla et al. (2014), Murugesan (2008), Paul et al. (2016)
AT1: I have a favorable attitude toward green purchase, green use, and green disposal. (N) AT2: I would like to choose digital devices with green features such as power management. AT3: People should be concerned about controlling the power consumption of digital devices. AT4: I like the idea of reusing, refurbishing, and recycling digital devices. (N) AT5: Pro-environmental user behavior is pleasant. (N)	
Subjective norm	Paul et al. (2016), Yadav & Pathak (2016)
SN1: Most people who are important to me think I should choose green digital devices. SN2: Most people who are important to me think I should use green digital devices. SN3: Most people who are important to me think I should dispose of digital devices in a pro-environmental way. (N)	
Perceived behavioral control	McCarty & Shrum (1994), Han et al. (2010)
PC1: It is entirely up to me to choose green digital devices in place of the conventional non-green ones. PC2: I feel that using green digital services is entirely within my control. PC3: I have resources, time, and opportunities to choose green digital devices and services.	
Ecological knowledge	Mostafa (2007)
EK1: I know how to enable power management features on my computer. EK2: I am very knowledgeable about environmental issues. EK3: I know how to reduce energy consumption while using digital devices. EK4: I know how to recycle digital devices in the right way. (N) EK5: I know where I can recycle unwanted digital devices. (N)	
Intention of pro-environmental user behavior in the electronics lifecycle	Francoeur et al. (2019), Molla et al. (2014)
IT1: I intend to use eco-friendly digital devices. (N) IT2: I intend to use eco-friendly digital technologies. (N) IT3: I intend to apply the power management features of digital devices I regularly use. IT4: I intend to recycle digital devices. (N) IT5: I intend to persuade others to dispose of digital devices pro-environmentally. (N) IT6: I intend to choose environmental-friendly brands for ecological reasons. (N)	
* N represents new items that we developed in this study based on the focus group discussions and related conceptual research.	

Appendix B

Table B1. T-test for Equality of Means

						95% confidence interval of the difference	
	t	df	Sig. (2-tailed)	Mean diff.	Std. err. diff.	Lower	Upper
Ecological belief	-0.516	98	0.607	-0.094	0.183	-0.457	0.269
Ecological attitude	-0.362	98	0.718	-0.064	0.177	-0.415	0.287
Subjective norm	-1.081	98	0.282	-0.260	0.241	-0.737	0.217
Perceived control	1.207	98	0.230	0.267	0.221	-0.172	0.705
Ecological knowledge	-2.387	98	0.019	-0.553	0.232	-1.013	-0.093
PUB intention	-0.859	98	0.392	-0.187	0.217	-0.618	0.244

Appendix C

Table C1. Descriptive Statistics for Multigroup Analysis

	ITP_L		ITP_H	
	Mean	**Std. deviation**	**Mean**	**Std. deviation**
Ecological belief	5.429	0.100	5.429	0.080
Ecological attitude	5.774	0.083	5.735	0.080
Subjective norm	4.512	0.130	4.591	0.113
Perceived control	5.260	0.100	5.035	0.106
Ecological knowledge	4.368	0.124	4.714	0.108
PUB intention	4.860	0.084	5.014	0.080

ITP_H: high level of IT proficiency—intermediate, advanced, expert users
ITP_L: low level of IT proficiency—fundamental and novice users

Appendix D

Table D1. Robustness Test Results

Bootstrapping	**5,000**	**6,000**	**7,000**
Path	**T statistic**		
Age → PUB intention	0.971	0.960	0.959
Ecological attitude → Ecological knowledge	6.020	5.919	5.948
Ecological attitude → PUB intention	6.703	6.752	6.680
Ecological knowledge → PUB intention	4.161	4.151	4.226
Ecological norm → PUB intention	3.758	3.848	3.762
Ecological belief → Ecological attitude	6.325	6.384	6.349
Ecological belief → Ecological norm	4.148	4.169	4.135
Ecological belief → Perceived control	5.017	4.939	4.942
Gender → PUB intention	0.330	0.328	0.331
Work experience → PUB intention	0.094	0.094	0.094
Perceived control → PUB intention	1.821	1.808	1.821

Appendix E

Table E1. Alternative Model Results

	Original sample	Sample mean	Standard deviation	T statistic	P values
Ecological attitude → ecological knowledge	0.371	0.379	0.062	6.003	0.000
Ecological attitude → PUB intention	0.387	0.385	0.065	5.965	0.000
Ecological knowledge → PUB intention	0.236	0.240	0.057	4.134	0.000
Ecological norm → PUB intention	0.229	0.226	0.060	3.795	0.000
Ecological belief → ecological attitude	0.504	0.512	0.079	6.359	0.000
Ecological belief → ecological norm	0.360	0.370	0.088	4.106	0.000
Ecological belief → PUB intention	0.021	0.018	0.055	0.383	0.701
Ecological belief → perceived control	0.346	0.355	0.070	4.921	0.000
Perceived control → PUB intention	0.107	0.112	0.061	1.758	0.079

Appendix F

Table F1. Robustness Check for Multigroup Analyses

Boot-strapping	5,000	6,000	5,000	6,000	5,000	6,000	5,000	6,000	5,000	6,000	5,000	6,000
	T value											
Age → IT	0.438	0.431	0.644	0.638	1.173	1.173	0.563	0.555	0.367	0.376	0.562	0.571
AT → EK	5.537	5.595	3.974	3.935	4.044	4.008	5.139	5.166	3.349	3.334	5.784	5.814
AT → IT	8.782	8.659	3.609	3.537	5.005	4.982	4.745	4.648	5.526	5.516	3.654	3.710
EK → IT	0.606	0.594	4.615	4.632	1.952	1.908	3.810	3.821	2.845	2.882	2.538	2.562
SN → IT	2.725	2.674	2.725	2.707	6.231	6.049	0.270	0.273	2.588	2.592	2.108	2.086
EB → AT	8.714	8.916	3.946	3.941	7.874	7.902	3.450	3.374	3.796	3.805	9.534	9.640
EB → SN	5.193	5.392	2.540	2.522	6.757	6.777	1.836	1.804	1.641	1.654	8.589	8.763
EB → PC	5.294	5.364	3.279	3.271	5.164	5.192	2.768	2.787	2.272	2.240	7.911	8.073
Gen→ IT	0.037	0.037	0.334	0.330	0.219	0.217	1.026	1.026	0.156	0.157	0.888	0.890
Exp → IT	0.443	0.436	0.389	0.398	0.510	0.495	0.496	0.484	0.127	0.132	0.027	0.028
PC → IT	0.335	0.337	2.427	2.424	1.115	1.120	1.458	1.456	2.845	2.801	0.025	0.024

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