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DESIGN CHALLENGES IN ENERGY CONSERVATION STRATEGIES FOR SHARED SPACES

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Abstract

Business and service buildings, mainly consisting of shared spaces, account for 38% of the total Singapore energy consumption. However, compared to energy use studies in private spaces (i.e., apartments, houses, etc.), there are far fewer studies on shared spaces. This paper describes the results of a user study conducted in four cohort classrooms at Singapore University of Technology and Design (SUTD). The user study was designed to gain insights into students' attitudinal and behavioural changes in response to energy feedback displays placed in their classrooms, and an inter-cohort classroom energy competition with monetary incentives. The research questions: (RQ1) which factors shape energy use behaviour and (RQ2) which factors shape energy users' responses to interventions aimed at sustainable behaviour, were formulated to explore shared space energy use behaviours. The results show that social dynamics, contextual forces such as policies on resource usage, and personal capabilities are playing roles in shaping energy use behaviours as well as shared space users' responses to interventions.

Keywords: Design for X (DfX), Sustainability, User centred design, Ecodesign

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1 INTRODUCTION

According to the Singapore Building and Construction Authority (BCA), business and service buildings account for 38% of the total Singapore energy consumption. Electro-mechanical systems and electrical devices are the main contributors to the energy consumed by these buildings. Currently, BCA and other regulatory authorities are pushing towards sustainable building through Green Mark Assessment Criteria and other green building initiatives. These regulations and initiatives are aimed at improving the efficiency of electromechanical systems, electrical devices, and the energy efficient architectural design of buildings. End-users or the occupiers of these buildings are not a focal point of these initiatives.

Research shows that end-users are the weakest link in the sustainability chain. Many environmental problems (e.g. global warming, water shortages, etc.) are rooted in user behaviours, and could only be managed by changing the relevant behaviours (Gardner and Stern 2002, Vlek and Steg 2007). The growth of consumption has overshadowed technical efficiency gains (Midden, Kaiser and McCalley 2007) of available energy efficient solutions.

Therefore, understanding which factors promote or inhibit environmentally significant behaviour is essential for developing energy efficient solutions and behavioral interventions (Geller 2002, Steg and Vlek 2009). In shared spaces (i.e., shared office spaces, classrooms, etc.), resources are shared between different individuals and groups, and energy use behaviors are subjected to social dynamics. These interactions between individuals and groups in shared space settings present a unique set of challenges to the energy intervention design process. Moreover, compared to energy use studies in private spaces (i.e., apartments, houses, etc.), there are far fewer studies on shared spaces. Our work focuses on understanding the potential of shared spaces for energy savings.

This paper describes the results of a user study conducted in four cohort classrooms at Singapore University of Technology and Design (SUTD). The user study was designed to gain insights into students' attitudinal and behavioral changes in response to energy feedback displays placed in their classrooms, and an inter-cohort classroom energy competition with monetary incentives. Surveys were used to elicit attitudes, values and energy use behavior of the participating students, before and one month after introducing the feedback displays to the cohort classrooms.

This paper is structured as follows. Section 2, Background, presents the research questions of the study and related models and theories on energy use behaviors and behavioral interventions. Section 3, Methodology, describes the design of the user study, the procedure followed, as well as the limitations. Section 4, Results and Discussion, presents the findings of the user study and key insights. Finally, Section 5, presents concluding remarks and implications for energy efficient design of shared spaces.

2 BACKGROUND

The aim of the user study described in this paper is to understand energy use behavior in shared spaces and intends to answer the following two research questions: **(RQ1)** which factors shape energy use behavior; **(RQ2)** which factors shape energy users' responses to interventions aimed at sustainable behaviour. Frameworks, theories, and models related to these two research questions are given in the following subsections.

2.1 Energy Use Behavior

Factors underlying environmental behaviour and relevant intervention strategies have been studied from different theoretical perspectives (Vinning and Ebreo 2002): learning theory; motivational, moral and value theories; theories of attitude, belief, or intention; and theories of emotion and affect.

Learning theory consists of operant conditioning or applied behavioural analysis approaches (Geller 1986, DeYoung 1993). These approaches are based on the assumption that behaviour can be modified if one changes its antecedents (e.g. provision of prompts, commitments, etc.) and consequences (e.g. feedback, rewards, penalties, etc.) (Porter et al. 1995). Although, these approaches are effective in promoting short-term behavioural changes, the cost to maintain them as long-term solutions is their biggest drawback (Vinning and Ebreo 2002).

Motivational, moral and value models and theories encompass norm activation (Schwartz 1977), actively caring (Geller 1995), value systems (Schwartz 1994), lifestyles (Leonard-Barton 1981), self-determination (Deci and Ryan 1985), and self-regulation (Sansone et al. 1996). The norm activation model and the actively caring model are based on factors inducing altruistic behaviour. Value system models explore personal values and their influences on consumption behaviour. Lifestyle related approaches explore effects of lifestyle choices such as “voluntary simplicity” (Iwata 1999) on consumption behaviour. In contrast to the self-determination theory where behaviour is assumed to be a function of self-determination, self-regulation theory assumes that behaviour changes are regulated by changing cognitions, emotions or perceptions (e.g. reframing experience to be more positive). These approaches provide alternative means to spur pro-environmental behaviour, where trade-offs (e.g. comfort, convenience, quality of life, etc.) are involved and rewards are not tangible.

Theory of reasoned action (Ajzen and Fishbein 1980) and theory of planned behaviour (Ajzen 1991) are based on attitude, belief, and intentions. Theory of reasoned action is based on attitudes and subjective norms, which are considered as the determinants of behavioural intentions and relate intentions to behaviors. The theory of planned behaviour is a derivative of this theory, where behavioural intentions are considered to be determined by three factors: attitudes towards behaviour, perceptions of social norms, and perceptions of behavioural control. However, these two models are not capable of representing the important roles of habits, self-control, associative learning and emotional processing in shaping behaviour (Michie et al. 2011).

Theories of emotion and affect address emotion and motivation (Dickerson et al 1992, Kals et al. 1999), structure of emotions (Sand 1999, Fredrickson 1998), and emotion and communication (Lord 1994, Mobley et al. 1995). Emotion has largely been ignored in studies exploring cognitive structures that predict conservation behaviour (i.e. environmentally efficient behavior) (Vining and Ebreo 2002). Smith et al. (1994) proposed that affective reactions may play a more significant role in predicting behaviour in situations where attitudes are weak. In addition, Grob (1995) proposed to include emotion in models of conservation behaviour.

Very few previous works (e.g. Black et al. 1985) have included systematic analyses of variables to represent differences in context (Steg 2008, Steg and Vlek 2009). In addition, there is a lack of studies into how a particular behaviour relate to the combination of other day-to-day behaviours, quality of life, and other trade-offs, rather than analysing them in isolation (Stern 2000, Selvefors et al. 2015, Steg and Vlek 2009). As an example, comparisons between energy use behavior in private and shared spaces would provide valuable insights into context-related factors. Furthermore, there is a lack of studies investigating the effects of factors across hierarchies (individual, community, and national levels). The shared-space energy use behavior study addresses the need for group-level studies.

2.2 Behavioural Interventions

The review of Abrahamse et al. (2005), and the meta-analysis conducted by Delmas et al. (2013) provide a comprehensive overview of applied behaviorial analysis based energy intervention studies. These interventions can be classified using the four types of factors influencing environmentally significant behaviours presented by Stern (2000):

- attitudinal factors (norms, belief, and values);
- contextual forces (e.g. social interactions, government policies and regulations, incentives, etc.);
- personal capabilities (knowledge, skills, availability of time to act, money, socio-demographic variables, etc.); and
- habits and routines.

In addition, Stern (2000) suggested using a combination of these factors to ensure the acceptance and usefulness of interventions.

Most of the intervention studies found in the literature focus on changing attitudinal factors. However, a declination of the relative explanatory power of social-psychological variables (e.g. attitudinal variables) was observed by Black et al. (1985), in a private space energy use study, due to the trade-offs between pro-environmental behaviour, convenience, cost, and quality of life. Therefore, frameworks and theories that combine a variety of factors can be used in formulating intervention strategies, in order to overcome the limited capability of interventions focused on one type of factors. Examples are ABC (Attitude- Behaviour-Context) theory (Guagnano et al. 1995) and VBN (Value-Belief-Norm) theory (Stern et al. 1999) that consider factors from the personal and contextual spheres together in formulating intervention strategies.

The study based on social norms (Schultz et al 2007) presents the importance of combining descriptive and injunctive norms (descriptive: perceptions on how others are actually behaving, and injunctive: the perceived accepted behavior) in reducing energy consumption or to maintain the consumption of low energy users, in order to avoid a rebound (boomerang) effect. In addition, Schultz noted that, in contrast to Europeans, Chinese indicated that they are affected by norms (Kasperson and Stern 2010) . This observation strengthens the importance of considering the heterogeneity of users in the intervention design process (Steg 2008, Steg and Vlek 2009), which is a challenge in a shared space.

3 METHODOLOGY

The shared-space energy use study was conducted in the guise of an inter-cohort classroom energy competition. In SUTD, first-year students are divided into cohorts (see Figure 1) consisting of roughly 50 students in each classroom. The lecturers and tutors are coming to the classrooms, and the students spend most of their time in classrooms during the first academic year. The timeline of the study is shown in Figure 2.

Figure 1. A typical cohort classroom

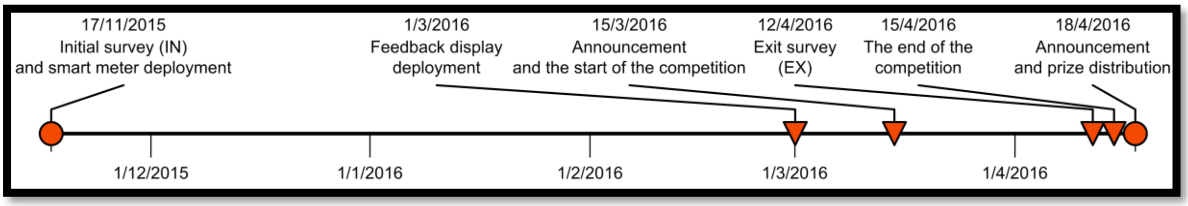

Figure 2. Timeline of the user study activities

Four classrooms were selected and an online initial survey (IN) conducted to collect quantitative (scale of 0-100) and qualitative responses to questions about attitude and behaviour concerning energy use (see Table 3). At the same time the four participating classrooms were equipped with smart energy meters. After stabilising the smart meters and the communication infrastructure, energy feedback displays were placed in the classrooms, and the competition was started with an announcement.

Table 1. Energy feedback display designs

Classroom	Allows comparison with Peers	Display update time
Cohort classroom 1 (see Figure 3A)	No	Hourly
Cohort classroom 2 (see Figure 3B)	No	Daily
Cohort classroom 3 (see Figure 3B)	Yes	Hourly
Cohort classroom 4 (see Figure 3B)	Yes	Daily

The displays did not show the energy consumption of the air-conditioners as these are controlled centrally. The exit survey (EX), again with questions about attitude and behaviour concerning energy use as shown in Table 2, was given at the end of the four weeks long competition. Three days later, the cohorts were ranked on the basis of the difference between their energy consumption "before" and "during" the competition, and awarded with cash prices (1000, 800, 600 and 400 dollars). The displays in the cohort classrooms were designed to allow a two-variable two-level experimental design (see Table 1 and Figure 3): 1) the displays showed energy consumption of either one classroom or all four classrooms, allowing a cohort to compare their behaviour with those of the peers, and 2) the displays were updated hourly or daily.

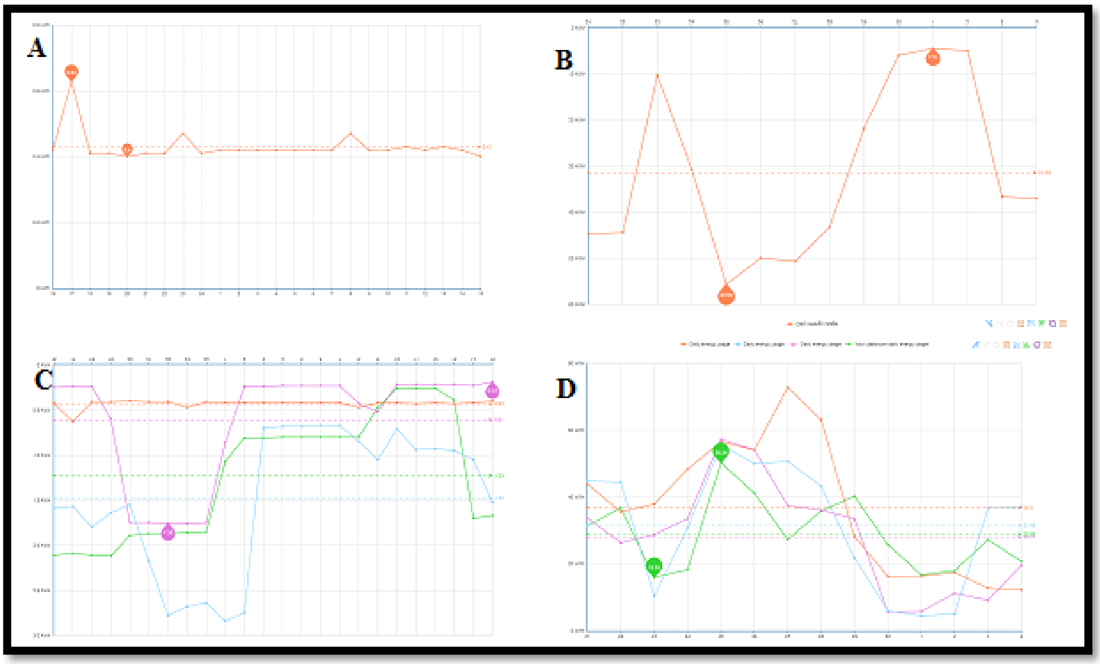

Figure 3.A to D: the display designs for classrooms 1 to 4 respectively. Displays C and D not only provide the energy use data of the classrooms, but also of the other 3 classrooms, allowing a comparison with peers. The highest and lowest energy consumption levels, of a the window, are indicated by bubbles

4 RESULTS AND DISCUSSION

Two interventions were incorporated in the study: the element of competition and the visibility (or not) of the energy use behaviour of the other cohort classrooms. Out of the 200 students, 81 and 68 complete responses were received for the initial survey (IN) and exit survey (EX) respectively. Only 37 respondents participated in both surveys. As shown in Table 2, the response distribution over the classrooms differed considerable between initial and exit survey. The surveys consisted of 9 questions (see Table 3) to be answered on a 100-point scale, and a number of open questions. We will first discuss the outcome of the quantitative responses, before discussing the qualitative responses.

The results of a "before" and "after" intervention comparison are presented in Table 2. The table shows a comparison of the mean values for each question between IN and EX surveys for all respondents assuming responses are independent of each other (using standard t-tests), and for the group of respondents that answered both surveys (the repeated respondents) (using paired t-tests). A parametric test was used here, due to the relatively larger sample sizes.

Only the group of respondents that filled out both surveys shows a significant increase of reported energy saving behavior (Q1) in their day-to-day activities. A significant increase of reported frequency of switching off devices in cohort classrooms (Q4) can be observed in general as well as in the group of repeated respondents. In the repeated group, a significant decrease can be observed in the reported attitudinal variable related to worrying about the inconvenience to other students by switching off devices that are not in use (Q6). This could be a resulting effect of the displays, incentives, and predominantly energy conscious EX respondents. Interestingly, although they are not significant, rebound effects can be seen in the reported attitudinal variable changes: reduction of the variable related to the significance of energy use (Q3), and the increase of the variable related to not consuming a significant amount of energy (Q7).

Table 2. Comparisons of response means between the initial (IN) and exit survey (EX)

			IN vs EX surveys in general n(IN)= 81, n(EX)=68				IN vs EX surveys for repeated n(IN and EX)=37			
			Mean	St. D.	T	P	Mean	St.D.	T	P
I try to save energy in my day-to-day activities	Behaviour	Q1 IN	68.8	20.6	-1.07	0.2850	65.7	21.1	**-1.73**	**0.0920**
		Q1 EX	72.3	18.6			72.6	17.4		
I always check and switch off lights, ….. before leaving my residence	Behaviour	Q2 IN	84.0	20.6	-0.60	0.5500	82.2	20.7	0.17	0.8640
		Q2 EX	86.0	19.7			81.4	22.8		
I think we waste significant amount of energy in the cohort classroom	Attitudinal	Q3 IN	59.7	30.6	1.20	0.2340	60.8	29.5	0.73	0.4730
		Q3 EX	54.1	27.1			56.8	26.2		
I check and switch off lights, … without any use in the cohort classroom	Behaviour	Q4 IN	69.5	29.8	**-2.10**	**0.0370**	68.8	26.8	**-3.16**	**0.0030**
		Q4 EX	78.4	21.8			81.1	20.2		
I switch off lights …I am the last person to leave the cohort classroom	Behaviour	Q5 IN	92.6	15.6	1.11	0.2680	91.4	17.1	-0.12	0.9080
		Q5 EX	89.9	15.0			91.7	12.3		
I am worried about switching off lights ……. inconvenience to other students	Attitudinal	Q6 IN	48.8	35.4	0.69	0.4880	53.8	36.3	**1.74**	**0.0910**
		Q6 EX	44.7	34.9			42.4	33.8		
We do not consume a significant amount of energy…. won't be able to save much….	Attitudinal	Q7 IN	31.0	27.5	-1.63	0.1050	32.0	25.3	-1.26	0.2170
		Q7 EX	38.2	26.5			38.8	25.4		
I can positively influence other students to cut down waste…..	Attitudinal	Q8 IN	56.6	26.4	0.85	0.3990	51.2	28.3	-0.87	0.3910
		Q8 EX	52.9	26.9			55.1	23.3		
I want to save energy and contribute towards a greener earth	Attitudinal	Q9 IN	85.5	17.5	1.16	0.2460	83.4	18.9	0.09	0.9290
		Q9 EX	82.3	16.7			83.2	15.5		

Table 3 presents the bivariate correlations between intra and inter survey variables. In the initial survey (IN), the reported overall energy saving behavior (Q1) is not reflected in the cohort classroom shared space by switching off unused devices (Q4). However, in the exit survey (EX) these two variables (Q1 and Q4) show a significant correlation. Interestingly, the reported attitudinal variable on saving energy (Q9) in initial survey (IN) is significantly correlated with the reported attitudinal variables: Q3 and Q8; and the reported behavioural variables: Q1, Q2, Q4, Q5, and Q8. On the other hand, the reported overall energy saving behaviour (Q1) in the exit survey (EX) is significantly correlated with the reported behavioural variables: Q2, Q4, and Q5; and attitudinal variables: Q8 and Q9. Therefore, the feedback displays and incentives seem to have influenced the conversion of the reported attitudinal correlations of IN into reported behaviours of EX. The negative effect of social dynamics on energy saving behavior is reflected in significant negative correlations between the reported attitudinal variable on worrying about other users (Q6) and some of the reported attitudinal and behavioural variables in IN, EX and IN and EX surveys: switching off devices in the cohort classroom when the last person leave (Q5), positively influencing others (Q8), and the reported overall energy saving behavior (Q1).

The repeated responses present a unique opportunity, where intra as well as inter correlations can be compared to investigate changes caused by the feedback displays and incentive-based interventions. The upper left quadrant of the correlation matrix, obtained for the repeated responses, resembles the IN survey correlations. Similarly, the lower right quadrant resembles the EX survey correlations. However, there are few missing significant correlations in the repeated responses that seem to be caused by the low sample size. The lower left quadrant depicts the consistency between IN and EX surveys, with five diagonal elements. Furthermore, the positive diagonal element corresponding to the reported attitudinal variable on worrying about the convenience of other users (Q6) depicts the undying influence of social dynamics in some cases.

We expected to see significant differences in attitudes and behaviors between the groups of classes received different display designs (see Table 1). Therefore, the reported attitudinal and behavioural variables (Table 2) of EX survey were investigated to identify significant differences between the groups: energy use comparisons not given (classrooms 1 and 2) vs. given (cohort classrooms 3 and 4), and daily (cohort classrooms 1 and 3) vs. hourly (cohort classrooms 2 and 4) updates. Non-parametric tests for medians (independent sample median test) and distributions (independent samples Mann-Whiteney U test and Kolmogorov-Smirnov test) were conducted, and no significant differences were found between these groups. However, as given in Table 4, the energy measurements show the lack of consistency between stated and revealed behaviors.

Table 3. Bivariate correlations between variables of initial (IN) and exit (EX) surveys

		n(IN)=81									n(EX)=68								
		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
I try…	Q1																		
Check resi.	Q2	(+)									(+)								
We waste	Q3																		
check	Q4										(+)	(+)							
…last…	Q5	(+)	(+)		(+)						(+)			(+)					
..worried…	Q6														(-)				
We do not	Q7			(-)															
..influence.	Q8										(+)								
I want…	Q9	(+)	(+)	(+)	(+)	(+)			(+)		(+)							(+)	

0.20-0.39	0.40-0.59	0.60-0.79	0.80-1.00	p<0.05 in all
"weak"	"moderate"	"strong"	"very strong"	

Repeated responses

		n(IN and EX)=37									n(IN and EX)=37								
		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Initial Survey (IN)	Q1																		
	Q2	(+)																	
	Q3																		
	Q4																		
	Q5	(+)	(+)																
	Q6																		
	Q7			(-)															
	Q8						(-)												
	Q9	(+)	(+)			(+)			(+)										
Exit Survey (EX)	Q1		(+)						(+)	(+)									
	Q2						(-)												
	Q3																		
	Q4				(+)							(+)							
	Q5					(+)								(+)					
	Q6						(+)												
	Q7																		
	Q8								(+)	(+)	(+)								
	Q9	(+)							(+)	(+)	(+)							(+)	

The results of the competition, i.e., the differences energy consumptions between "before" and "during" the competition, are shown in see Table 4. Assuming that the working habits in the classrooms were the same for all cohorts, assuming if work habits changed during the competition, they changed in all cohorts in a similar way, and assuming that the incentive of monetary prizes for winning the competition are the same for all cohorts, Table 4shows that the two cohorts that were only shown the energy consumption of their own classroom saved less than the two classrooms that did see the consumption of the other classrooms. This is what we expected. Contrary to our expectation, is the following observation: for the same type of display, the classroom that had a daily update saved more than the one with an hourly update. Also contrary to our expectation, cohort 1, despite being part of a competition to save energy, actually increased their energy consumption. Possible reasons are an incorrect the assumption concerning the role of incentives (at least in this situation) and other factors, such as a different workstyle. Although interesting, the findings concerning actual energy consumption are not conclusive because of a variety of limitations, not the least the limited number of classrooms involved.

. Table 4. Energy consumptions "before" and "during" the competition

		Term Weekdays Average Energy Consumption		
	Display allows comparison	Before (kWh)	During (kWh)	Savings (%)
Classroom 1	N	38.3	49.1	-28
Classroom 2	N	57.1	50.2	12
Classroom 3	Y	52.0	43.1	17
Classroom 4	**Y**	**48.1**	**35.3**	**26**

The qualitative responses received for the open-ended questions (see Table 5 and Table 6) provide more insights into the slight rebound effects observed in the quantitative results. As shown in Table 5, the students are not happy about the lack of control of the central air-conditioning unit (consumption was not included on the energy display) and the lights. Although, during the user study the students were informed about the exclusion of the energy consumption of the central air-conditioning unit, their unhappiness with the current policies of operation (no user controls) is strongly reflected in the exit (EX) survey as well. It seems that the energy awareness induced by the displays has made them further unhappy about the too-cold or too-hot settings of the central air-conditioner.

Table 5. Qualitative responses from the initial (IN) and exit (EX) surveys

	Initial n(IN)=81		Exit n(EX)=67	
	Things that make difficult to save energy	**Things that will help to save energy**	**Things that will help to save energy**	**Observed behavior changes**
Policy	Lack of user controls (48)	Extending user controls (67)	Extending user controls (38)	
Building design	Lack of accessibility to switches (10) Lack of natural ventilation (1)	Improved accessibility to switches (21) Improved natural ventilation (9)	Improved accessibility to switches (5) Improved natural ventilation (6)	
Use behavior and interventions	Inefficient energy use behavior (of self/others) (22)	Energy use information (29) Incentives (8) Efficient energy use behavior (22)	Energy use information (2) Incentives (8) Efficient energy use behavior (19)	Checking the energy feedback (6) Switching off unused devices (5) Using low energy settings (1)
Automation		Smart or automated solutions (10)	Smart or automated solutions (21)	
Other	Weather, projects and other exogenous factors (11)		Other workplaces (7)	

Table 6. Qualitative responses from the exit survey (EX) related to the feedback display

	Exit n(EX)=67			
	How display encourages you	**Things you like about energy display**	**Things you do not like**	**Suggestions to improve**
Visual representation	Increased energy use awareness (13)	Graphical representation (28) Visualizing and increasing energy awareness (36)	Graphical representation (10) Lack of clarity and details (15)	Graphical representation (4) More details and comparisons (7)
Location			Inconspicuous placement (11)	Strategic placement (12)
Effectiveness	Gamification (7)		Ineffective and consumes energy (18)	Alternative strategies (3)

A clear shift can be observed in proposed solutions in the IN and EX surveys from self-regulating (improved accessibility and energy use information) to smart or automated solutions. The students have stated that they would like to have smarter classrooms and adaptive controls to automatically switch-off devices and to automatically adjust air-conditioning, lighting, and other conditions in the cohort classroom, based on the occupancy and environmental conditions.

Generally, students are happy about the features of the feedback displays, and increased energy awareness due to the displays as well as the incentives/gamification (see Table 6). The main suggestions are to improve the positioning of the energy displays by placing it in a more conspicuous place and to improve the presentation to make it more attractive and informative. As in any other group, some of them were happy about the graphical representation and few of them were not happy. Alternative and more impactful representations (in dollar values, etc.), information to benchmark (energy consumption of a typical classroom, apartment, etc.), and strategic placement of displays can be potential solutions for the students' concerns.

5 CONCLUSIONS

This paper presents a user study conducted in four cohort classrooms at Singapore University of Technology and Design (SUTD) to understand factors affecting energy use behavior in shared spaces, and responses of shared space users to energy interventions. Energy feedback displays and an energy competition with monetary incentives were used as interventions. Initial (IN) and exit (EX) surveys were conducted to obtain quantitative and qualitative responses from the students, in addition to the energy use observations.

The first research question, **(RQ1)** what factors shape energy use behavior, provided many insights about differences between energy use behaviors in private and public spaces. The reported attitudinal and behavioural variables indicated the significant role played by social dynamics such as worrying about the convenience of other users. This seems to be a key factor affecting the translation of energy saving attitudes and energy efficient behaviors in private spaces to energy efficient behaviors in shared spaces. The students have stated about the inefficient energy use of their colleagues as a challenge to save energy. In addition, their almost neutral position on positively influencing other students portrays the challenges presented by social dynamics. This seems to be the reason for the shift between the initial (IN) and exit (EX) surveys' energy saving suggestions from self-regulating (energy use information and improved accessibility) to smart and automated solutions.

The second research question, **(RQ2)** which factors shape energy users’ responses to interventions towards sustainable behaviour, provided a more systematic overview of the challenges towards greener shared space behaviors. Slight rebound effects were observed in two reported attitudinal variables related to the amount of energy use in the classrooms. These rebounds may be caused by the effect of descriptive norms (small amount of energy used by them) and the inability to control the biggest energy consuming device, the centrally controlled air-conditioner. Clearly, the contextual force of the air-conditioner control policy has an adverse effect on the interventions. In addition, design flaws such as accessibility of switches, and lack of control given to individual lights (instead of lighting zones) are the main factors identified from the qualitative responses. Policy, layout design, and the social dynamics factors compounded together can directly conflict with the energy efficient behavior. Therefore, a special attention is needed for the processes of policy and control layout designing in shared spaces.

The key insight obtained in this user study is the need for system level solutions as energy interventions in shared spaces. In addition, students' suggestions to implement smart solutions to steer clear of conflicts, related to switching off devices, show the opportunities for smart devices. However, feedback displays, incentives, gamification or other interventions will not be sufficient to reverse the adverse effects of policies and design flaws. This study reinforced the need for understanding the contextual forces and capabilities of the users to promote energy efficient behaviors in shared spaces. We will extend this work by investigating the effect of different resource control policies on energy consumption through energy simulation studies.

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