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Designing an IoT-enabled Gamification Application for Energy Conservation at the Workplace: Exploring Personal and Contextual Characteristics

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Abstract This paper focuses on determining the important factors that must be considered when designing and developing a gamification application that educates employees in workplaces, towards a more sustainable energy consumption behaviour. We have conducted on-site surveys, as well as unstructured interviews with employees from three different workplaces where we will deploy the app. We present our key findings and propose specific insight and guidelines for experiments aiming towards energy conservation at the workplace through behavioural change. We conclude that the individual contextual characteristics of workplaces lead to the availability of different energy conservation behaviours that can be acted upon by the employees. At the same time, the employees' preferences for the gamified app include, among others, a collaborative game scenario – that features both intrinsic as well as extrinsic rewards based on the individual participant profile. This research is conducted in the course of a H2020 EU funded project, through which an IoT-enabled energy monitoring platform for workplaces will be developed, with the ultimate goal to change the employees' energy consumption behaviour through a gamification application.

Keywords: • Energy Conservation • Gamification • Workplace • Employee Behaviour •

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1 Introduction

Commercial and industrial sources in the US produced three times the CO2 emissions of residential sources in 2010 (Lülfs and Hahn, 2013), while the buildings sector also consumes 20% of the total delivered energy worldwide (Conti et al., 2016). At the same time, the commercial sector features the fastest-growing energy demand, with its consumption projected to grow by an average of 1.6% per year until 2040 (Conti et al., 2016). More importantly, buildings account for 30–45% of the global energy demand, with commercial buildings, and primarily office and university buildings, classified amongst those presenting the highest energy consumption and savings potential (Gul and Patidar, 2015). Therefore, it is important to increase our efforts towards energy conservation in commercial buildings and workplace environments, towards addressing the worldwide recognised issue of energy wastage.

Albeit the documented effect of public buildings on energy consumption, only a limited body of research focuses on employees' energy consumption behaviour, which can certainly play a significant role in the buildings' energy footprint. Aiming to contribute to this research path, we are participating in an H2020 EU project (2016-2019) that develops a platform, which utilizes Internet of Things (IoT)-enabled smart meters, smart plugs, and low-cost sensors (e.g. NFC, iBeacons) to monitor energy use and, simultaneously, wastage per work device, area and employee. The ultimate goal of this research project is to use the accurate energy consumption data collected from the interconnected devices/things in order to transform the employees' energy usage behavior.

Gamification, "the use of game design elements in non-game contexts" (Deterding et al., 2011), has been identified as an instrument that, when appropriately utilised, could lead to employees' energy behaviour change. It can support companies to change behaviours, increase and sustain employee engagement and productivity (Webb, 2013), (Pickard, 2015). Furthermore, the active use of gamification for the improvement of business processes results in amplified workers' positive psychology, and strengthens positive emotions, engagement, relationships, the sense of meaning, as well as accomplishment (Uskov and Sekar, 2015). Thus, we were inspired to build, in the course of the project, a gamification application that receives input from the IoT-enabled platform and provides real-time recommendations to employees in three participating pilot sites, motivating and educating them to adopt a more green behavior.

To design an effective gamification app that the employees will adopt and use, we had to consider two important factors during the app's user requirements analysis: (i) employee personal profiles, needs and preferences, as well as (ii) workplace contextual characteristics. We first performed on-site visits to identify the contextual characteristics of the three different workplace environments that participate in the project. Then, we conducted a series of semi-structured interviews with representative employees (potential app users), to formulate a more holistic view of the three sites' special requirements. Our primary focus was on collecting useful insight towards the design of a gamified app that matches the needs and preferences of its end-users, as well as serves the contextual limitations and opportunities of the pilot workplaces. In the next sections of the paper we begin by reviewing related work presented in the literature, discuss our observations through the site surveys, as well as our findings through interviews with employees, and conclude with our future research plans.

2 Related Work

2.1 Energy consumption in Workplaces

Energy in public buildings is mostly consumed through space heating and cooling systems – typically the largest energy consumption sources both in the EU and the US (Nguyen and Aiello, 2013) – lights, refrigerators, computers, and other equipment. Additionally, occupant behaviour is an important factor in the consumption of energy in buildings, as it can add, or save one-third to a building’s designed energy performance (Nguyen and Aiello, 2013). However, unlike private households, users at workplaces have by default no direct financial incentive to minimize energy use within their office workspace. Therefore, motivations, as well as incentive structures, for users in organizational settings are different, as no personal monetary gains are normally expected from a change in behaviours. Hence, more altruistic motives, like supporting the organization in energy and monetary savings, contributing to environmental protection, or complying with expectations from colleagues and superiors, can be leveraged to engage in energy saving behaviour at the workplace (Matthies et al., 2011).

Studies in energy consumption behaviours emerged with the oil crisis of the 1970s, from a wide range of disciplinary perspectives (Stephenson et al., 2010). Specifically, the findings of a meta-analysis of 156 published information-based energy conservation experiments encouraged us to explore the occupants’ energy behaviour in public buildings (Delmas, Fischlein and Asensio, 2013): (i) non-monetary, information-based strategies can lead to an average reduction in electricity consumption by 7.4%, (ii) monetary incentives, in contrast, lead to a relative increase in energy usage rather than inducing conservation, (iii) energy conservation through behavioural change should be considered alongside efforts to reduce energy consumption through technological improvements. Overall, a limited number of studies exist regarding energy conservation in a work environment, compared to household contexts. Very few studies have also investigated employee energy-related behaviours, none of which involving inter-organisational comparisons (Lo, Peters and Kok, 2012).

2.2 Gamification for Energy Efficiency purposes

The basic and most well-known gamification elements are points, badges and leaderboards – a useful starting point for gamification efforts – but a number of additional game elements exist (Werbach and Hunter, 2012). Single elements can fulfil different functions, but in interaction with each other they can have varying and complex motivational effects (Sailer et al., 2013). The MDA (mechanics-dynamics-aesthetics) framework is widely used to categorise gamification elements (Zichermann and Cunningham, 2011). A commonly stated objective behind using gamification is to encourage behaviour change, in the form of increased participation, improved performance, or greater compliance (Seaborn and Fels, 2015). At the same time, gamification in a work environment can focus on business processes, or outcomes, involving participants, or players, both from outside and/or inside a firm, to improve employee satisfaction (Robson et al., 2015). When organizational goals are aligned with participants' goals, organizations can achieve their goals as a consequence of players achieving their goals, and employees can become fully engaged with new company initiatives (Dale, 2014). Furthermore, since gamification often involves storing and processing personal, potentially sensitive data, this could lead to "transparent employees" within company boundaries and, at the same time, inappropriate extrinsic incentives might crowd out intrinsic motivation (Blohm and Leimeister, 2013). Workplace gamification also needs to apply to long-term, apart from initiative-specific, objectives (Reiners and Wood, 2015). In a corporate setting, players have also tend to be more invested in intra-group, than in inter-group, competition (Nikkila et al., 2011). Gamification might also contradict with some personality types and cultural norms (Shahri et al., 2014), highlighting the importance of designing gamified applications to match their potential users' profile, by assessing their respective characteristics, as well as preferred game mechanics (Uskov and Sekar, 2015).

More specifically, various studies have suggested gamification as a means for motivating energy efficient behaviour. Grossberg et al. conducted a thorough review of gamified energy efficiency initiatives concluding that saving energy is highly rewarding in itself, and the greatest achievement a gamified app could aim for is to outline this fact to its users. Furthermore, they note that energy savings in the range of 3-6% have been reported on a number of studies featuring the application of gamification to reduce energy consumption, with an achievable possible savings of more than 10% (Grossberg et al., 2015). Inspired by the forementioned information, we decided to conduct a thorough observation of the three targeted workplaces, as well as a detailed exploration of the characteristics and preferences of our prospective gamified app participants. Our ultimate goal was to ensure that we will design and develop an effective gamified app that motivates employees towards a more energy-conscious behaviour.

3 Identifying Context and User Requirements

3.1 Physical observation of the workplaces

The gamified app will be deployed and pilot-tested in three different workplaces – participating in the forementioned EU-funded project – that are located in different European countries. The first workplace is a public office in Athens, Greece, which provides IT support to the facilities of its home organisation, both locally, as well as in an on-site calling schedule. There are 55 employees and 14 separate rooms, whilst normally no visitors are hosted. Interestingly, almost a third of the employees are usually out of office, on on-site visits, therefore consuming less energy in general. The highest consumption of energy occurs for heating/cooling through the air-conditioners. Consumption varies, according to the position of the sun relative to the building's façade. In the summer, cooling is mostly needed in the afternoons, while, in the winter, heating is mostly needed in the mornings. Therefore, the energy usage patterns are affected by: time of day, external temperature and cloud coverage.

The second workplace is an electricity regulation agency in Barcelona, Spain, employing 49 employees in total. The building is always open and visitors in the floor covered by the agency are limited. The floor layout includes 1 open-space office area, 8 individual offices, 5 meeting rooms, 1 waiting room, 1 kitchen and restrooms. Employees cannot directly alter the climate conditions in the building, they can however open windows. External temperature and humidity conditions affect energy consumption, while around 40% of electricity consumption is due to air conditioning, as heating is provided by natural gas consumption. Smart meters are installed for monitoring the energy consumption per category of use (i.e., lighting, air conditioning), but no specific strategy for reducing energy-consumption has been set.

The third workplace is a public museum at the old City of Luxembourg. It comprises of 4 buildings, containing the exhibition rooms and 25 administrative offices. There are 100 employees in the museum, 40 of which administrative staff. Lights are always on in the exhibition area and visitor restrooms, during the museum's visiting hours. There are very few automated light switches and, although the daylight prevails in the museum rooms, many lights are kept on for security reasons. The largest part of energy consumption is due to lighting and the climate system in the exhibition rooms, which ensures the museum exhibits are secure and properly preserved. Heating in the administrative offices is controlled per office (1-2 people in the room) where there is no air-conditioning. Employees cannot alter the climate or lighting conditions in the largest part of the facilities, and museum visitors cannot act on the climate controls or any other energy consumption actuator. At a first glance, only the lift usage of visitors may alter their contribution to energy consumption in the museum.

Overall, through the physical observation process a number of common, as well as contradictory significant characteristics of the three pilot workplaces were highlighted. Table 1 summarizes our most important findings.

Table 1: Workplace characteristics to be considered for the design of the gamified application

	Public Office		**Electricity Regulation Agency**		**Public Museum**	
Workplace Location	Offices in single floor		Offices in single floor		Three buildings	
Nature of work	IT support, on and off-site		Office work		Museum, office back-end	
Number of Employees	55		49		100	
Visitors	almost none				~65.000 / Year	
Main energy offending devices & availability to interact with them through the gamified app	PCs- Monitors Fancoils Lighting Printers Coffee Maker Toaster	Y Y Y Y Y Y	PCs- Monitors Fancoils Lighting Printers Coffee Maker Toaster Kettle Microwave	Y N Y Y* Y Y Y Y	PCs- Monitors Fancoils Lighting Printers Coffee Maker Microwave	Y N Y* Y Y Y
			*all shared units		* not in exhibition -only in offices	
Other possible energy conservation behaviours available	Windows Elevators	Y Y	Elevators	Y	Elevators * for employees & visitors	Y*

The museum is different to both the other workplaces, in that it hosts a very large number of visitors per year, whereas close to no visitors are expected in the other two sites. At the same time, the climate and lighting conditions in most of the areas of the museum are very specific and, therefore, lights and climate control cannot be used in a gamified app for these areas. Furthermore, it consists of four whole buildings, as opposed to a single floor office space. The only area of the museum that resembles the other two workplaces is the employees' backend office area. A special, distinctive feature of the museum is that its visitors could conserve energy by opting to use the stairs instead of the elevator.

Regarding the office spaces in all three sites, a lot of similarities exist in the possible targeted behaviours. PCs, monitors and printers can be switched off more often, as well as lights, when not needed. Common area equipment – kettles, coffee makers, toasters and microwave ovens, depending on their availability on each site – can also be introduced to a gamified app. Such shared equipment, as well as shared printers and lights, could be used in a game, by creating special rules to allocate points according to each individual's energy conservation.

3.2 User Interviews: Method and Results

We performed in-depth, semi-structured interviews with a representative sample of employees per workplace, as a small amount of interviews can produce data capable of addressing a set research goal, selected with careful sampling and a thorough collection technique (Holloway, 1997). Furthermore, following the theoretical saturation rule of qualitative research, we sampled until no new information or insight was produced – 26 employees – also exceeding ten cases in consistence with the suggested valid range of case sampling (Eisenhardt, 1989).

Table 2: Interview Guide

Demographic info & role in organisation
Working conditions in terms of comfort and stress
Do you have your own office or do you share it with others?
Do you think that energy conservation is a real need or a business hype? Do you think energy consumption is mostly an environmental, or an economic problem?
Do you personally save energy at work? Give an example.
Do you turn the screen off when you leave the office for a while? Do you like to read on paper in general?
Do you consider yourself more energy efficient at home than at work?
Are you married? Do you have children? Are they energy-efficient?
Do you generally feel colder, or hotter than people around you?
Do you consider saving energy at work your personal responsibility?
Do you think that more energy can be saved at work? If yes, name as many cases as you can identify where energy is wasted at work.
Do you do anything about this waste? Do you think that your own actions matter or only collective actions may have an impact towards this end?
Do you think that a reward is deserved for being energy-efficient at work? Monetary or not?
If the reward is small, is it still motivating or discouraging for you?
Would you change your behaviour to save more energy at work?
Do you play games in general? What kind?
Do you own a smartphone? Do you use mobile apps?
Do you prefer competitive or collaborative games? If we were creating a game at work around energy efficiency, would individual or team competition be preferable to you? Would you prefer a collective goal setting over a competitive setting for this game?

Our intention was to gain a first understanding of the employees' habits, needs and preferences regarding energy consumption and gamified apps. We conducted a discussion starting from specific questions, but the order of questions was changing according to the order of the subjects discussed. We intended to elicit mostly spontaneous answers and we encouraged the participants to add their remarks in the end of the conversation, as they saw fit. Moreover, all information collected during the interviews was content analyzed and coded by three independent coders into categories pertaining to the present research. A number of categories were decided upon ahead of time (e.g. Game Element of Point, Badge etc.) while other categories were identified based on the employees" responses (e.g. setup of teams). In the case of disagreement on the classification of any particular statement, the disagreements were resolved upon joint discussion. Table 2 includes the questions used to stimulate the conservation. Respectively, Table 3 reports the feedback we received from the employees during the interviews.

Table 3: Summary of employee interview results

	Public Office	**Electricity Regulation Agency**	**Public Museum**
Interviewed Sample	5 / 55	9 / 49	12 / 100
Gender	4 Male – 1 Female	5 Male – 4 Female	3 Male – 9 Female
Role	Various: management(2), administrative (1), app. developer (1), technician(1)	Various: project mgt. (3), admin.(2), waste mgt.(1), energy efficiency (1), comms (1), finance (1)	Various: administrative (5) security-technical (3), managerial (3), scientific (1)
Shared (vs own) office	5/5	5/9	8/12
Energy conservation is a real need	3/5	5/9	12/12
I save energy at work	3/5	5/9	11/12
Feeling colder / hotter than other people	1/5 feel colder	4/9 feel colder	4/12 feel hotter, 4/12 feel colder
I consider saving energy at work my personal responsibility	2/5	7/9	9/12
Identified cases where energy is wasted at work	5/5: monitors-printers on standby, air-conditioners	9/9: lights, appliances left on afterhours”	10/12: heating, printers, elevators
Personal, or collective actions have impact?	2/5 personal, 3/5 collective	4/9 personal, 5/9 collective	7/12 personal, 5/12 collective
Reward is deserved for being energy-efficient	2/5	5/9	2/12
Even small rewards are motivating to me	1/5	2/9	7/12

I play games in general	3/5	5/8	5/12
Competitive vs collaborative game, Individual vs team play	3/5 collaborative-team competition	5/9 collaborative-team competition	8/12 collaborative-team competition
Game Goals: Collective vs Competitive	1/5 collective, 1/5 competitive	4/9 collective, 3/9 competitive	4/12 collective, 1/12 competitive
Special group-based electricity consumption behaviour	Technicians & IT print less. Administrative do most of the printing	Employees in open plan area share printers and lights.	Employees in exhibition area do not have access to many energy-saving actions.
Main problems identified by the interviewees	• Air Conditioner temperature not always set optimally. • Lights left on after operating hours or used when ambient light suffices. • Screens and printers left on stand-by mode when leaving. • Windows opened with the air conditioner on	• Air Conditioner temperature very low in summer. • All lights ON even with few people, or ample natural light, in open space and common areas • Screens and printers left on when unused • Excessive printing • Coffee maker left on • Windows open with air conditioner on • Elevator overly used	• No control over Air Conditioning, Lights, or opening Windows in the exhibition areas by employees, due to restrictions • Screens, Printers, PCs, Monitors often left on standby mode • Elevators could be used less

Based on the interview results, we can deduce a number of suggestions, regarding the differences and characteristics that a gamified application towards energy conservation should respect. First of all, the varying roles of the participants in the three sites seem to affect their daily duties, as well as their opportunities to act upon specific energy conservation actions. For example, some need to print a lot of documents according to their duties, while others not at all. At the same time, the employees in the exhibition area of the museum, for example, do not have access to many energy saving actions in general. Secondly, working in a shared space presents further challenges towards designing a gamified app, as the individual actions of the participants also affect their colleagues, and therefore a level of cooperation towards common goals in the game may be preferable in these situations. Comfort levels are a parameter that also needs to be addressed, as the actions of the participants in a game, should not impede on the personal comfort of their colleagues, or lead to tension and disagreements. We should also take into account that some of the participants feel colder/hotter than their colleagues and this issue should not preferably be exacerbated by an app. Interestingly, when asked whether personal or collective actions have an impact on energy conservation at their respective workplaces, the participants were somewhat equally divided, indicating that the game should provide opportunities for both personal and collective actions to be acted upon.

The necessity of interviewing the prospective participants of a gamified app towards energy conservation was also demonstrated by the fact that different cases where energy is wasted are unanimously identified by the participants in the three different sites: At the "Public Office", monitors and printers left on standby upon leaving, at the "Energy Agency" lights and appliances left on afterhours and, at the "Museum" heating, printers and elevators. As per the main problems that employees identified at their respective workplace, regarding energy consuming devices: Employees at the "Public Office" suggested that air conditioner temperature is not always set optimally, lights are left on after operating hours or used when ambient light suffices, screens and printers are left on stand-by mode when leaving and windows opened with the air conditioner on. At the "Energy Agency", the air conditioner temperature may be very low during summer, all lights are left on even when a few people are present in commonly used areas – or when ample natural light suffices, screens and printers are left on when unused, excessive printing is reported, coffee makers are often left on afterhours, windows are opened with the air conditioner on, and the elevator is overly used by the employees that avoid using stairs instead. At the "Museum", employees have no control over air conditioning, lights, or opening windows in the exhibition areas due to restrictions, screens, printers, PCs and monitors are often left on standby mode and elevators could probably be used less. All these actions can be targeted through a gamified app, according to the specific needs of each site, towards attaining the optimum behavioural effect on energy conservation.

As only some of the prospective participants, in two of the three sites, consider saving energy at work their own personal responsibility, the ones that do could be selected as leaders in a team-play scenario, so that they can provide positive role models for their fellow team mates. Furthermore, since both personal and collective actions are considered to have an impact on energy conservation by some of the participants, a gamified app towards that end should instigate both individual, as well as collective actions. This is further supported by the fact that on all sites the majority of the participants prefer a collaborative game with team competition, while the minority a competitive game featuring solo play. The same stands for collective vs competitive goals. An additional interesting finding is also that varying percentages of employees in the three sites believe that a reward is deserved for being energy-efficient at the workplace as well as that the existence of even small rewards is motivating towards the same target. Therefore, a gamified app would be more efficient through the inclusion of tangible rewards, only for a percentage of employees. Depending upon the general trend on each site, as well as their availability by employers, the app could also selectively include these extrinsic means of motivation, to adhere to each specific situation. Finally, as only about half of the participants on all sites play games in general, a gamified app featuring only basic game elements and not an overly complex narrative or gameplay, could be more universally accepted, as well as effective, towards behavioural change.

Through the interviewing process, the participants' also provided some additional interesting insight, regarding what we should consider when designing a gamified app towards energy conservation at their workplace. The most prominent suggestions were:

- "Every single small action is important but in the end only collective actions will have a really deep impact."
- "We have to conserve energy responsibly for our future and because we want to do it, not to collect rewards"
- "If we combine all the small consumptions, they may add up to a considerable amount of energy saving. The information of how much each device consumes in standby mode should be provided to the users"
- "In view of the great differences between the tasks of the Museum's staff, I do not see any possibility for competitive games. A collective goal can be more interesting."
- "The game should have specific rules and a clear target"
- "Any awards should be divided between users, based on their contribution in the game."
- "The gamified system should not make people feel guilty about their energy consumption"

4 Conclusion

A body of research exists, regarding energy conservation in public buildings, due to their large share in energy consumption worldwide. The use of ICT has also been featured in a number of studies aimed at energy conservation in public buildings. However, the effect of such solutions is limited by the building occupants' intentions to follow specific energy consumption behaviour. Gamification has been introduced in various contexts to instigate behavioural change, including energy conservation initiatives, where it has been utilised as a means to affect occupant behaviour. The results from the relative studies have been mixed, as well as difficult to compare, due to the vast differences in both the actors' and contexts' characteristics.

Aiming to amend this issue, we have followed a structured process, involving two steps: On-site visits to prospective pilot sites, as well unstructured interviews with a representative sample of the participants in future gamified apps aimed at energy conservation. We have provided the questionnaire used in the interviewing process, so that it can be used in future similar studies. Through our analysis, we have discovered a number of contextual differences between the pilot sites, as well as in the prospective participants' available, suggested and preferred actions towards energy conservation at their respective workplaces. At the same time we have also gathered insight, regarding the game related preferences of our participants in our field of application. By combining all this information, we can design a gamified application to better match both our future participants' context, as well as preferences, leading to an overall better-suited solution to a better-defined problem. Therefore, we expect the effectiveness of our resulting application to be enhanced, compared to cases where neither the context, nor the preferences of the prospective participants of a gamified app have been analysed in advance.

Based on our findings, we have identified the main elements that affect the design of a gamified application towards energy conservation in the three workplaces surveyed. Employee roles and daily routines, existing limitations towards specific behaviours within the workplace (e.g. standard procedures - SOPs), the layout in the workplace (shared workspaces vs individual offices), existing employees' comfort levels, and different opportunities to conserve energy in each workplace, affect the accessibility, as well as impact of specific energy saving actions that can be included in a gamified app. As per the app design itself, in our pilot sites, both personal and collective actions, individual and team play should be considered, while – since only a few of the employees play games – a basic game play could be more effective in energy behaviour change.

Apart from its merits, our study also bears some limitations. First of all, we have investigated our prospective participants, by interviewing a sample (12.74 %) of employees. Therefore, our findings would be better grounded, if we were given the opportunity to interview all of the employees at the sites we visited. In addition, we conducted the on-site visits only once in each site, whereas a longitudinal study could provide more accurate results, as well as additional insight not currently recorded. Finally and more importantly, we expect that the validity, as well as usefulness of the methodology we propose, would be significantly enhanced, by a practical application of our findings in an actual gamified energy conservation experiment that would be conducted in our surveyed pilot sites. We aim to proceed towards this direction through our research in the future.

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