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Energy Saving by Gamification Method: Case Study at a Public School, Thailand

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Abstract – *Nowadays, Thailand has a problem of insufficient energy supply, which has caused Thailand an energy insecurity problem. So the Government of Thailand has announced to all government agencies, including public schools, to reduce their energy consumption. However, it is not simple to fulfill this task due to many obstacles, called "Barriers". The purpose of this paper is to examine the effectiveness of a gamification method, which enables schools to create energy saving behavior among its students. A pilot case study was programmed at Sri Ayudhya School where a game named "Power School" was played by 134 students and the data collected using CCTV and questionnaires. Paired t-test statistics was used to evaluate the students' behavior from participating students and their parents after the pilot study, combined with the records from CCTV. The results from this paper highlight how gamification has significant positive effectiveness to a student's energy saving behavior at 95% confidence. Therefore, it can be seen that this gamification method is an alternative tool for public schools to improve the energy saving behavior of their students, which can affect the total energy consumption of the schools going forward.*

Keywords – energy conservation, energy saving, gamification, public school, Thailand.

1. INTRODUCTION

In the present world, no one can deny that energy is very important to all of us. However, most of the energy we are using these days is from petroleum, which is non-renewable energy and will be depleted in the near future. The U.S. Energy Information Administration, (EIA) announced in 2013 that the world had oil reserves only for the next 25 years based on an energy reserve survey and the current consumption ratio [1]. Thailand, which imports more than 10,682 million kWh of energy from neighboring countries each year [2], has also recognized the energy shortage problem. On 19 February 2013, a Thai cabinet resolution announced that the government of Thailand had set a goal for all government agencies, including public schools, to reduce energy consumption by 10% from 1,881 GWh of total energy consumption by year 2015 [3].

Sri Ayudhya School, one of the most important public middle schools in Thailand, established since year 1951, located in metropolitan Bangkok, and educating students for both junior and high school, was also affected from the Thai government policy for energy saving. The total number of students in Sri Ayudhya School is more than 3,200, with more than 143 teachers and staff in a total of 71 classrooms in 7 buildings, and is categorized by the Thai Ministry of Education as an Extra Large School. Although Sri Ayudhya School participated in an Energy Mind Award campaign which was operated by the Metropolitan Electricity Authority (MEA) in order to educate and support students and staff in energy and environment savings**.**

Referring to the previous study about energy saving barriers in school, we found a result which mentioned that one of the most important barriers that obstructs public schools from energy savings is the "Values" type barrier. This refers to the life style of today's student, who values environmental and energy issues with less of a priority when compared to their personal convenience and comfort [4]. Due to the fact that the behavior of students in school has a direct impact on energy consumption there, the management of Sri Ayudhya School has to find innovative ways which are suitable for energy users in the school, in order to change energy wasting behavior and create energy saving behavior among its students.

The concept of Gamification is becoming a new trend in many sectors, such as business, marketing and services in today's world, as a tool to influence and motivate groups of people [5] and support the introduction of new patterns of behavior as well as the modification of habitual behavior [6]. Therefore the goals of this study are to examine the effectiveness of gamification methods in effecting students' energy consumption behavior in school, by selecting Sri Ayudhya School as a pilot case study and using questionnaires and observation to collect research data.

2. BEHAVIOR AND ENERGY SAVING

As to the worldwide energy waste problem, many previous studies have been researched and mentioned user behavior is a key barrier to obstructing energy savings (Kiatruangkrai and Leerarasmee [4]; Brown and

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Sherriff [7]; Nagetha and Belachandra [8]; various methods, such as Environmental Education [9] and Energy Feedback [10] have been used in order to provide awareness and change user behavior, which can lead to saving energy and energy efficiency. However, there are still some limitations due to different consumption patterns and requirements of users in each type of building. A study from van Elburg [11] has shown that the Feedback method has some difficulty changing user behavior due to the difficulty of feedback measuring and persistence of feedback. In addition, those methods were mostly developed in order to change household behavior, which normally receives direct impact from their own consumption in the form of energy bills, this has many differences from the users in an organization such as a public school, because most users in the school do not have to take any responsibility for their consumption, this kind of situation is called a "Principal-Agent problem" [12], in that users do not have to be concerned about the energy bill because the school will take care of it, this means there is no incentive to motivate them for saving energy at the school. It's not only the Principal-Agent relationship which can obstruct the users in an organization from saving energy, there are also many other kinds of negative behavioral and personal attitudes, such as a 'feeling of insignificance in the population', the 'others will do: syndrome', 'resistance to change', 'busy with routine functions', and 'dependence on others for help' [8].

3. GAMIFICATION AND BEHAVIOR

The concept of Gamification is quite new in the academic world, it only emerged in 2008 in the digital media industry and became more widely adopted in 2010 [13]. According to many studies, the definition of gamification is the concept of applying game elements into non-game contexts in order to improve people's experience, engagement and behavior (Bunchball [5]; Ribeiro and Ventura [14]; Zichermann and Cunningham [15]). Although the concept of gamification is still young, it has grown and developed very fast, as we can see from a search of hit records, which increased more than 200% from year 2010 to 2013 [16]. It has also been used by many businesses and services to support the behavior of users, such as by increasing user activity, or influencing the quality and productivity of their actions [17]. Not only in the business world, but also many schools now use games as part of their teaching method for subjects such as math in order to increase a student's attention [18]. There are also many examples of how to use games to develop behavior of young people, such as LunchTime, a game that facilitates learning and reflection and promotes positive dietary attitude changes [19]. A game prototype developed at the University of California, Berkeley, designed new applications based on behavior change theory, which can be used to improve wellbeing and health [20] and The Kukui Cup, a game application which used to improve electricity saving behavior in dormitory of University of Hawaii [21]. Therefore, it can be seen that the gamification method has the potential to change and support students' energy saving behavior at Sri Ayudhya School.

4. METHODOLOGY

4.1 Time and Location

This study was scheduled for 3 weeks during the 1st semester of 2016, there were 3 classrooms participating in this experiment, rooms 4/1, 4/2 and 4/3, all three classrooms are located on the 5th floor of building number 7 in Sri Ayudhya School and have similar electric equipment, such as air cooler, electric fan, microphone and projector.

4.2 Participant

The participants in this experiment totalled 134 persons (30 male and 104 female) from 3 classrooms, they were purposively selected by the director of Sri Ayudhya School to participate in this research due to the similarity of those classrooms such as number of students, location of classrooms, and electrical equipment. All of the participants were studying in year 1 of their senior middle school and were in classrooms 4/1, 4/2 and 4/3. In addition, their parents also participated by giving evaluation scores for each student's behavior in a questionnaire.

4.3 Observation

Observation is one of the most widely recognized methodologies for yielding a representative sample of a subject's naturally occurring behavior, and has been used with much research into human behavior, such as in a study from Wells and Lo Sciuto, [22]. During the 1st week of this experiment, closed-circuit televisions (CCTV) were installed inside the 3 classrooms in order to observe the energy consumption behavior of students. All cameras were set for recording from 8.00 am until 5 pm, according to the normal classroom schedule, in order to record the students' energy consumption behavior before and after the gamification experiment.

4.4 Gamification Experiment

After observation, the participants were introduced to a web-based game named "Power School", which was developed and gamified by turning the daily behavior of students into energy saving behavior in school, such as by turning off the lights during lunch break, turning off air coolers after finishing class, *etc*. Power School created by adding the top 3 most popular game mechanics to motivate a student's energy saving behavior, suggested by Hamari *et al.* [16] were used as follows: Points, Leaderboard and Achievement. Not only gamification was used to create Power School but also the techniques of consequence intervention were used in game design, such as commitment and incentive [23] in order to fulfill the game play by starting from quest selection (commitment) and reward (incentive) to the game winner at the end of experiment. A sample of the Power School screen can be found in Figure 1.

Fig. 1. Sample of Power School screen.

Fig. 2. Sample of activity selection screen.

Table 1. Summary of energy saving activity (Quest).

Quests	Sub-Quests
1. Light bulbs	Do not turn on lighting bulbs until start the morning class
	Turn off lighting bulbs during lunch break
	Turn off lighting bulbs when left school in the evening
2. Air Cooler	Do not turn on air cooler until start the morning class
	Turn off air cooler 10 minutes before lunch break
	Turn off air cooler during lunch break
	Turn off air cooler 10 minutes before left school in the evening
	Turn off air cooler when left school in the evening
3. Electric fans	Do not turn on electric fans until start the morning class
	Turn off electric fans during lunch break
	Turn off electric fans when left school in the evening
4. Projector	Do not turn on projector until start the morning class
	Turn off projector during lunch break
	Turn off projector when left school in the evening

The Power School game allows each student to log in using a password, they then customize their own avatar and choose an energy saving activity (Quest) which they want to do each day, these activities (Quests) were created based on the Guidebook to Reducing Energy Consumption for Government and State Enterprises, which was provided by the Ministry of Energy, Thailand [23] which encouraged people to turn off electrical equipment during off-work time, in this case will be referred as “no class” time, the sample of activity selection screen can be seen in Figure 2.

In addition, there are two challenges activities which are turning off air cooler 10 minutes before lunch break and after school. Those activities (Quests) are summarized and showing in Table 1.

The students performed their daily activities as usual, however, they needed to be aware of the activities which relate to the quest that they selected. For example, if a student chose to turn off the light after finishing class, he or she had to perform it or remind someone in the class to do it. Those behaviors were recorded by CCTV cameras in each classroom, at the end of each day, the administrator checked those records and gave a score to each student as their individual score, which was summarized as a classroom (team) score, and which the student could check from the game leaderboard.

After 2 weeks of the experiment, the winning classroom was to receive a reward in the form of free movie tickets, and all participants and their parents were asked to answer the questionnaire in order to evaluate their energy consumption behavior before and after the gamification experiment. Paired t-test statistic by SPSS was used to analyze the data from the questionnaire and confirm the hypothesis of this study: that gamification method can improve a student’s energy saving behavior.

5. RESULT

5.1 Observation before Gamification Experiment

From CCTV records during 1 week of observation, many energy wasting behaviors by the students were captured and counted according to sub-quests in Table 1 those behaviors can be summarized and showing in Table 2.

From Table 2, we can see that students in class 4/2 had highest energy wasting behaviors while students in class 4/1 had the lowest wasting behaviors among those three classrooms. The example of wasting behaviors can be seen from Figure 3 showing that the light bulbs and electric fans were turned on during lunch break.

Table 2. Summary of wasting behaviors before gamification experiment.

Energy wasting behaviors	Classroom		
	4/1	4/2	4/3
Use lighting bulbs before start the morning class	1	1	2
Use lighting bulbs during lunch break	3	1	2
Use lighting bulbs after school in the evening	1	4	3
Use air cooler before start the morning class	2	2	1
Use air cooler during lunch break	2	2	1
Use air cooler after school in the evening	-	1	1
Use electric fans before start the morning class	-	4	1
Use electric fans during lunch break	-	5	5
Use electric fans after school in the evening	-	1	1
Use projector before start the morning class	-	-	-
Use projector during lunch break	-	-	-
Use projector after school in the evening	1	-	-
Total count	10	21	17

Fig. 3. Light bulbs and electric fans were turned on during lunch break.

The results from this observation confirmed that the students at Sri Ayudhya School have energy wasting behaviors during school time, an important barrier for Sri Ayudhya School, which is trying to reduce their energy consumption, so the school needs to find ways to change those behaviors. It was useful to know the results from observation before the experiment, which led to the question, "Can gamification methods improve students' energy saving behavior?" That result will be identified during the experiment.

5.2 Gamification Experiment

After 2 weeks of the experiment, checking the log-in data collected from the database indicates that all students from classrooms 4/1, 4/2 and 4/3 participated in the experiment. The winning classroom was 4/1, with a 16,115 score, the runner up was 4/2, with a score of 11,360 (an adjusted score by weight, adjusting the score to 50 persons for all classroom, is 16,786.45 and 13,853.65, respectively). The highest individual score which any student performed was 395, while the lowest was 105, the summary of Power School results are shown in Table 3.

Questionnaires were provided to all students who participated before and after this experiment by using the same questionnaire, in order to evaluate behavior, attitude and ability from students, 126 questionnaires were filled in and returned, which was 94% of total participants. The questions in the questionnaire were separated into 5 sections; section 1 was for the general information of the student, section 2, 3 and 4 covered their self-evaluation of energy consumption behavior, attitude toward energy saving, and ability to perform energy saving in school while section 5 was the energy saving behavior of students which evaluated by students' parent.

Table 3. Summary of results from gamification experiment.

	Classroom		
	4/1	4/2	4/3
No. of students	48	41	46
Total score	16,115	11,360	8,960
Adjusted total score	16,786.45	13,853.65	9,739.13
Highest score	380	350	395
Lowest score	250	220	105

In section 2 to 5, students and their parents were asked to give a score, which is a ratio scale ranging from

1-5 (Likert scale). The ratio scale ranges from 1-5 and was suggested by Dawes [24], due to it being quite simple to read the complete list of scale descriptors, and can readily be transferred to a 7-point equivalency using a simple rescaling method if required. Students and parents have to evaluate on their own, before and after the experiment. The ratio ranged from 1-5, with a score of 1 meaning "Very wasteful" and a score of 5 meaning "Very saving".

The selected statistic was paired t-test analysis (pretest-posttest) which was used to compare and identify if Gamification Power School can improve the energy saving behavior, attitude and ability of students by comparing mean of before (pretest) and after (posttest) experiment using score data from the questionnaires. So, the hypothesis of this research is that gamification can improve energy saving behavior of students, the Null hypothesis (H0) will be set as the students' behaviors, attitude, ability and evaluation from parents remaining the same without any changes, as follows:

H0 : $\mu 2 = \mu 1$: (Remain the same after the gamification experiment)

H1 : $\mu 2 \neq \mu 1$: (Different after the gamification experiment)

By using an SPSS program, data were calculated by function paired t-test analysis at 95% confident interval ($p < 0.05$), and provided results summarized of section 2 to 5 as shown in Table 4.

Table 4. Paired t-test results for student's evaluation before and after experiment.

Evaluation from questionnaires before and after gamification experiment	N	r	Mean	S.D.	t	p
Energy saving behaviors	126	0.49	2.37	3.01	8.86	0.00
Attitude toward energy saving	126	0.43	2.57	3.90	7.39	0.00
Ability to save energy	126	0.44	3.02	3.84	8.84	0.00
Evaluation of students' behavior from parents	126	0.43	2.44	4.18	6.55	0.00

* $p < .05$

From the results in Table 4, we can conclude that the students' energy saving behavior, attitude toward energy saving, ability to save energy and evaluation from parents, before and after the gamification experiment were moderately and positively linear correlated ($r = 0.49, 0.43, 0.44$ and 0.43, respectively), so it confirmed that paired t-test can be tested and accepted results showing are as follow:

There was a significant average difference between the mean of the students' energy saving behavior, which was evaluated before and after the gamification experiment ($t = 8.86$, $p < 0.001$). The energy saving behavior of the students after the experiment improved on average by approximately 2 point, as we can see from the "Mean", which is equal to 2.37

There was a significant average difference between the mean of the students' attitude toward energy saving, which was evaluated before and after the gamification experiment ($t = 7.39$, $p < 0.001$). The attitude toward energy saving of the students after the experiment improved on average by approximately 2 point, as we can see from the "Mean", which is equal to 2.57.

There was a significant average difference between the mean of the students' ability to save energy, which was evaluated before and after the gamification experiment ($t = 8.84$, $p < 0.001$). The energy saving behavior of the students after the experiment improved on average by approximately 3 point, as we can see from the "Mean", which is equal to 3.02.

There was a significant average difference between the mean of the students' evaluation from parents, which was evaluated before and after the gamification experiment ($t = 6.55$, $p < 0.001$). The energy saving behavior of the students after the experiment improved on average by approximately 2 point, as we can see from the "Mean", which is equal to 2.44.

From the results from paired t-test, it is clear that after the experiment, the evaluation score from all sections showing $p < 0.05$ which rejected H0 and accepted H1 it means that the students' behaviors, attitude, ability and evaluation from parents were changed after the experiment and changed in the positive way as the score after experiment increased more than the score before experiment.

So, it can be seen that gamification had a positive effect toward improving not only the student's energy saving behavior but also attitude, ability and evaluation from parents. However, in order to reconfirm this result, the observation results during the experiment were investigated further.

5.3 Observation during Gamification Experiment

The CCTV records from observations during the experiment were examined to reconfirm the improvement of the students' energy saving behavior, although there were some wasteful energy behaviors still captured, many improvements in energy saving behavior were performed by the students, such as waiting to turn on the air cooler until the class started, turning off the lights and electric fan during the lunch break and not turning them back on until the class started in the afternoon, a sample of the evidence pictures can be found in Figure 7.

Fig. 4. Turned off lights and electric fans during lunch break.

Fig. 5. Turning off the air cooler 10 minutes before finishing school in the evening.

Table 5. Summary of wasting behaviors during gamification experiment.

Energy wasting behaviors	Classroom		
	4/1	4/2	4/3
Use lighting bulbs before start the morning class	3	2	3
Use lighting bulbs during lunch break	3	3	3
Use lighting bulbs after school in the evening	2	2	2
Use air cooler before start the morning class	2	2	2
Use air cooler during lunch break	4	1	3
Use air cooler after school in the evening	1	2	-
Use electric fans before start the morning class	-	3	2
Use electric fans during lunch break	-	4	3
Use electric fans after school in the evening	-	2	2
Use projector before start the morning class	-	-	-
Use projector during lunch break	1	1	-
Use projector after school in the evening	-	-	-
Total count (2 weeks)	16	22	20
Average count per week	8	11	10

Furthermore, the challenging saving behavior of turning off the air cooler 10 minutes before the lunch break or end of school in the afternoon were performed many times by students. This behavior is very challenging because the students have to pay attention to the time in order to meet the requirement, and they have to prepare to be less comfortable after the air coolers are turned off until the class is finished. A sample of evidence pictures can be found in Figure 8. From evidence recorded by CCTV, it was confirmed that gamification can improve a student's energy saving behavior, the number of energy wasting behaviors by the students during experiment can be summarized and showing in Table 5.

Therefore, it can be seen from results of the paired t-test analysis and observation that gamification methods can improve a student's energy saving behavior, not only their energy consumption in school, but it can also affect their consumption behavior at home which can be observed by parents. The evidence from observation during the gamification experiment also emphasized the results provided from paired t-test analysis, that many improvements in a student's energy saving behaviors were captured and recorded.

6. DISCUSSION AND CONCLUSION

6.1 Discussion

These results suggest that students were engaged by the game elements and were reminded to be aware of their own energy consumption behavior, including their classmate's behavior. Individually and as a class, students in classes 4/1, 4/2 and 4/3 were affected from gamification in terms of behavioral changes toward a more energy saving behavior. From the competition part, it was very interesting to identify how the winning classroom had a good strategy and planning by having meeting and discussion of quest selection. The result is showing that they almost all selected similar quests each day, so it was easy to recognize and successfully perform their quests, while in the other two classrooms, each student selected a variety of quests based on their own interests, so it was more difficult for them to recognize and help each other to fulfill their selected quests, In addition, the results also showing that the

interaction to realize energy saving of students in class 4/1 was more than the other two as we can see from the records that many of students from class 4/2 and 4/3 omitted to select daily quest or performed uncompleted quest selection, while class 4/1 rarely had due to regularly meeting within their class.

After the experiment, free movie tickets were awarded to the winning classroom. The top 10 scoring students in the other two classrooms were awarded movie tickets, as well. About 85% of the students who got rewarded and were registered accepted their tickets. So this illustrates that correct incentive/reward can provide the necessary impact to support behavioural change among students. In addition, it was also determined that Sri Ayudhya School has the potential to overcome barriers and reduce their energy consumption in school by using these gamification methods. Not only can their energy bill be reduced due to the students' energy saving behavior, but an educational benefit can also be created, which can fulfil the goal of the school, which is to teach its students knowledge and good manners, and then possibly the students can transfer that to their family and friends.

6.2 Conclusion

Results of this study provide strong evidence that gamification methods have positive effectiveness, which can improve a student's energy saving behavior and possibly lead to a decrease in electricity use at Sri Ayudhya School. By using the questionnaire for self-evaluation, the student's energy consumption behavior before and after the experiment reconfirmed the results of the parent's evaluation and the observation records as a research method.

While it may not be possible for students to achieve 100 percent success with their quests due to many external factors, such as unexpected class schedule changes, we cannot see the energy consumption dramatically decreased. At least at Sri Ayudhya School, however, we can find potential ways to reduce energy costs while educating the students to have more energy saving behavior, not only in school but also at their own homes. Nonetheless, it is difficult to know if the energy saving behavior of students can remain sustained and long lasting due to the limited time for this study. If Sri Ayudhya School can often promote their energy saving campaign or competition by using gamification (such as on a monthly period), it is possible to maintain the students' energy saving behavior without losing their recognition.

There are still some research gaps from this study that require future research, to identify the relationship degree between the behavioral changes that resulted and game elements (mechanics and dynamics), such as challenges, leader boards, status, achievement, etc., or a combination of these factors. In addition, it would be interesting to study about the effective of energy saving recognition from team and team leader in the future research if they are related to the higher interaction to realize energy saving of students in winning class. Furthermore, feedback technology needs to be developed in order to check records, examine, calculate and provide energy consumption as the number of uses or cost by using algorithm programming linked with CCTV records. For example, one could examine the pictures collected from CCTV in every few minute to ascertain if there are any differences (such as between turning on/off electronic devices), if yes, the algorithm in the program could calculate energy cost as a result, so it would be useful for Sri Ayudhya School to have more information regarding its energy reduction so as to better prepare the school's policy in the future.

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