SCIPEDIA Journal of Dawning Research

The Effects of Energy Efficient Behavior Reminders on Electricity Conservation in a New York Public High School

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Abstract

Excessive electricity consumption negatively affects the economic growth of developing countries, and is a major cause of carbon emissions throughout the globe. This experiment investigated how the use of energy efficient behavior reminder affects electricity conservation in a New York City Public High School. In this experiment, during the first 10 days of the experiment, custodians were not reminded to turn off lights. From Day 11-20, reminders were sent to custodians every Monday and Fridays to turn off the light. During Day 21-30, reminders were sent everyday to remind custodians to turn off the lights. The results showed daily reminders had a significant decrease in electricity consumption compared to when no reminders were sent, but there was no significant difference between the percentage of lights being on, making it difficult to confirm if the custodians followed the reminders. The reminder of turning off lights was not a major source of electricity consumption and other factors might have consumed a larger portion of electricity.. More schools should be studied in order to validate the results. Future studies/research can test the effects of energy saving behavior reminders on electricity conservation from turning off electronic devices, such as smart boards or computers, at the end of the day.

OPEN ACCESS

Published: 04/07/2024

Keywords:
reminders
electricity
CARBON EMISSIONS
CARBON DIOXIDE EMISSIONS
Lights

Introduction

1.1 Issues of Electricity Consumption

Electricity contributes greatly to carbon emissions. Carbon dioxide and other greenhouse gasses trap heat in the form of solar radiation within the atmosphere, leading to an increase in the global water temperature and overall global temperature (Raval & Ramanathan, 1989). An increase in global temperature can disrupt the equilibrium of Earth's ecosystems, leading to adverse effects for both people and animals. For instance, as a result of increasing carbon dioxide levels, oceans have become more acidic. The increased acidity makes the ocean uninhabitable to marine life and upsets the balance of the ocean ecosystems (Cornwall, 2021).

In the U.S., 32% of the overall amount of carbon emissions came from electricity usage (U.S. Energy Information Administration, 2020), making it an important factor to consider if the US wants to achieve net zero emissions by 2035 (U.S. Department of Energy, 2023). It was also found that, in the EU, 20% of all carbon dioxide produced comes from electricity use, also making it important in curbing the carbon emissions in Europe (Eurostat, 2023).

Behavior, habits, and awareness relating to electricity usage play a role in electricity conservation. One study revealed that providing feedback on electricity through a website led to a 15% reduction in electricity use in residential households (Vassileva et al., 2012). Another study found a 13% reduction in electricity usage when a feedback system that allowed office workers to compare electricity use with others was used (Gulbinas & Taylor, 2014). Therefore, it is clear that altering behavior can be an effective strategy to conserve electricity.

1.2 Purpose and hypothesis

The objective of this study is to investigate the effects of energy-efficient behavior reminders on electricity conservation in a New York City Public High School setting. It was hypothesized that energy-saving actions implemented through behavior will reduce electricity consumption in a high school setting when they are implemented daily. Schools, a major source of energy usage, contribute to a large amount of the current carbon dioxide output. This large contribution can be attributed to the fact that 12.5% of New York's population is made up of students. (Anonymous, 2022) (US Census Bureau, 2023). To reduce energy consumption as well as the resulting carbon output, New York schools must decrease the amount of electricity used. By using a New York public high school as a model, the effectiveness of altering behavior on electricity use can be gauged in a public school setting and could potentially be applied to several public high schools both in and outside of New York.

1.3 Literature Review

There have been several studies that have attempted to reduce electricity usage or develop more environmentally friendly, energy-efficient devices. For instance, it was found that by replacing compact fluorescent lamps (CFL) with light-emitting diodes (LED), a 33-35% reduction in lighting energy expenditure can be seen. A further reduction of 13-15% can be seen if smart LEDs were used instead of LEDs (Moadab et al., 2021). The reduction in electric lighting energy usage can lead to a decrease in carbon emissions. Several studies have also made improvements to heating, ventilation, and air conditioning systems (HVAC). One such instance is the use of the Berkley Retrofitted and Inexpensive HVAC Testbed for Energy Efficiency (BRITE) on the Berkeley campus, which adjusts depending on the temperature to prevent a room from overcooling. BRITE was found to be 30-70% more energy efficient compared to two-position control, another way HVAC is controlled (Aswani et al., 2011). Another example can be seen in the development of solar-powered air conditioners. Solar-powered air conditioners rely on solar energy, which does not result in the production of carbon dioxide. In addition, solar-powered air conditioners are

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more energy efficient than conventional air conditioners, providing an incentive for their use (Zheng et al., 2018). The development of environmentally friendly devices and the illustration that they work demonstrate that there is great potential in reducing the amount of electricity consumed.

While studies testing electricity depletion and behavior have been done previously, there are few instances where the impact of energy-efficient behavior reminders on electricity consumption was investigated in a high school setting. Several studies have observed how habits such as turning off appliances (G. Kavulya, B. Becerik-Gerber, 2012) or one's political ideology (Gromet et al., 2013) have influenced electricity conservation, but these were often done in offices or residential buildings and were not explored previously in a New York City public high school. By investigating this context, the study seeks to fill a critical gap in the research done on electricity consumption in school settings, exploring whether behavior reminders can be effectively tailored and implemented in educational institutions to promote energy conservation. The unique aspect of this study is its focus on the effectiveness of behavior reminders in a high school setting, particularly within a New York City public high school. This focus on a high school setting underscores the importance of understanding how energy-saving interventions have to be modified in order to fit different institutional contexts due to how they differ in size, layout, and management compared to other contemporary settings, such as a residential building or office. A school building is designed not only to provide education, but also for extracurricular activities or programs such as sports or clubs. Additionally, most of the rooms within a high school are classrooms, which lack the typical amenities seen in residential buildings such as hydraulic systems and are not always in operation. Moreover, the focus on daily reminders adds novelty to this research as by examining the behavior changes in an educational institution, this study can help identify methods to reduce electricity usage and carbon emission in schools. Furthermore, the study's use of real-time data collected over days, weeks, and months provides a more accurate and credible assessment of electricity consumption compared to traditional methods that rely solely on monthly electricity bills.

Methods

2.1 Preparation

Prior to sending any reminders, the number of classrooms and room numbers were recorded onto an Excel spreadsheet before the experiment. This was done to eliminate the process of skipping any classrooms and to keep the data collected as consistent as possible. Additionally, every Sunday an email was sent to our AP Science coordinator to call the custodian's supervisor to relay the messages on specific days (Depending on the experimental group). The timing of the call is completely dependent on the AP Science coordinator. The custodian supervisor will then relay the message to the custodians. The message told to the custodians was not disclosed, but it was hypothesized that they were told to look out for any lights during their shift.

2.2 Experimental Setup

From Days 1 to 10 of the experiment, there were no reminders sent to custodians. Following that, from Days 11 to 20, reminders were sent to custodians through direct contact every Friday and Monday. Then, from Days 21-30, reminders were sent to custodians through direct contact every school day. During the beginning of the school day, the amount of classrooms with light and smartboards on were recorded between 7:10 AM and 7:20 AM for 20-30 minutes. Other aspects were not included in this experiment. The control group consisted of no reminders to custodians throughout the whole duration of this experiment. The first experimental group consisted of reminders every Monday and Friday to turn off the lights and smartboards. The second experimental group consisted of reminders every day to custodians to turn off lights and smartboards.

Table 1. Experimental Setup

Time	Reminder Frequency	Content of Reminder
Day1 - Day 10 (control group)	No	N/A
Day 11 - Day 20 (Experimental group 1)	twice /week (Monday and Friday)	To turn off the lights
Day 21-30 (Experimental group 2)	Weekday (Monday to Friday)	To turn off the lights

2.3 Measurements/Data Collection

The electricity consumption was accessed from the website "http://nuenergen.com" and recorded onto a 4 GB USB drive. Every Friday, the website was accessed from an office on the first floor of the school. When accessing the website, it was crucial to select the correct school, time, and day of the data being recorded. Specifically, the electricity consumption was recorded in 15-minute increments. After exporting onto the USB drive, it was then taken home and analyzed on Saturday. The data was then analyzed and put into Excel. After the experiment was over, the data was averaged out and compared to other experimental groups by using the line/bar graph function in Excel. Furthermore, the number of lights turned on for each floor of the building was recorded and compiled into an Excel spreadsheet. The data was then averaged out by doing (% of light on) / (total # of lights) and compared with other experimental groups using the bar graph function on Excel.

2.4 Safety

To ensure safety for the participants, when recording data on the number of rooms with either smartboard or light on, they were not allowed to touch anything in the room. A supervisor knew when the participants were performing the experiment in case of any incidents. Additionally, the participants moved carefully throughout the halls when observing classrooms.

2.5 Data Analysis

The amount of electricity, in kilowatt-hours, was accessed from the website "http://nuenergen.com" and recorded onto a 4 GB USB drive. The data on the percentage of classrooms and electricity consumption was stored in an Excel spreadsheet. The mean and standard deviation were calculated using the function in Excel. The percentage of lights was calculated by dividing the number of classroom lights by the total number of classrooms. The data was put into a bar graph and the electricity consumption was put into another line graph. It was then compared to see if the impact of setting reminders can reduce electricity consumption. With the data, it was then put into ANOVA to find if there was a significant difference. ANOVA (Analysis of variance) was used on https://astatsa.com/OneWay_Anova_with_TukeyHSD. A decrease in electricity consumption was considered significant if the p-value from the ANOVA test was less than 0.05.

Results

3.1. Evening Electricity Consumption

Figure 1. The comparison between the reminders sent per week and the average electricity consumption from 6:00 PM to 7:15 AM.

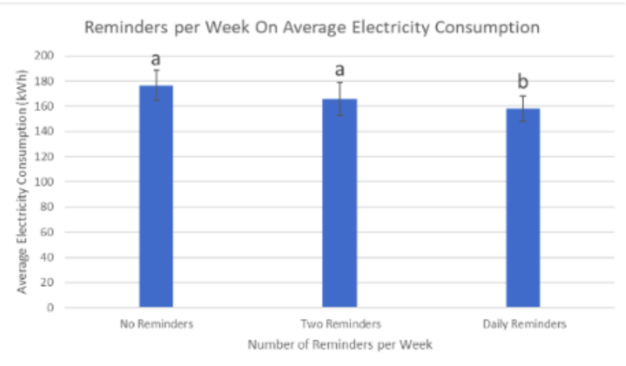

Figure 1. The comparison between the reminders sent per week and the average electricity consumption from 6:00 PM to 7:15 AM. The error bars represent the standard deviation. ANOVA with Tukey HSD was used to determine the significant difference. Groups labeled with the same letter (a) are not significantly different.

For the two weeks each group was investigated under, the overall energy consumption of each day was added together and then averaged to obtain the average electricity consumption observed under the feedback system. Figure 1 compares the average electricity consumption overnight between 6:00 PM and 7:15 AM between the no-reminder, two-reminder, and daily reminder groups (Figure 1). There was no statistically significant difference between the no reminders and two reminders groups ($p = 0.21$), an indication that the use of two-reminders does not lead to a significant reduction in electricity. There was, however, a statistically significant decrease observed between the no reminders and the daily reminder groups ($p < 0.05$), indicating that the implementation of daily reminders did reduce the average electricity consumption of the school. This is consistent with the hypothesis, which stated that the implementation of daily reminders would lead to a reduction in the electricity consumption.

3.2. Percentage of Lights On

Figure 2: The comparison between the reminders sent per week and the average percentage of lights on.

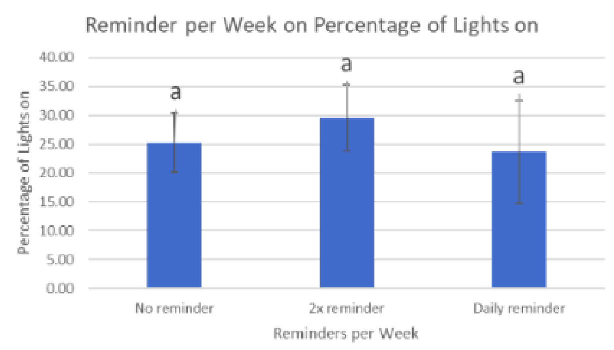

Figure 2. The comparison between the reminders sent per week and the average percentage of lights on. The error bars represent the standard deviation. ANOVA with Tukey HSD was used to determine the significant difference of experimental groups compared to the control group. Groups labeled with the same letter (a) are not significantly different.

A total of 91 classrooms were investigated each day to determine the percentage of lights turned on. Figure 2 compares the differences between the percentage of lights turned on for the no reminders, two reminders, and daily reminders groups (Figure 2). It was observed that no statistically significant difference was observed in the number of lights turned on or off between the no reminder group and the two-reminder group ($p = 0.11$). A similar result was found between the no reminder and the daily reminder groups ($p = 0.31$). This meant that the implementation of reminders did not meaningfully change the percentage of lights turned on. This runs contrary to the hypothesis, which predicted that there would be a significant reduction in the percentage of lights turned on.

3.3. All Day Long Electricity Consumption

Figure 3: The comparison between the reminders sent per week and the average electricity consumption for all day long.

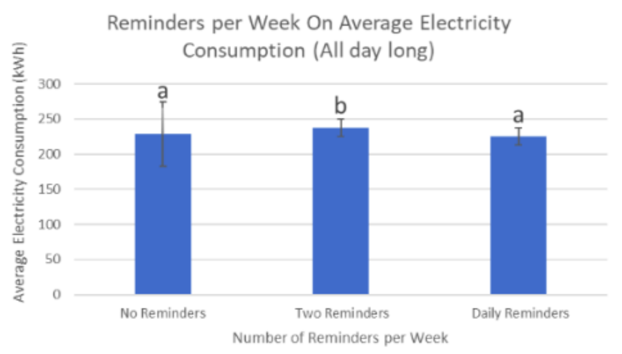

Figure 3. The comparison of weekly reminders to average daily electricity consumption is shown. Groups include no reminders (6 days), infrequent reminders (10 days), and daily reminders (8 days). Data from certain days were excluded: 4 days in the no-reminders group due to heating-related spikes and 2 days in the daily reminders group due to school holidays. The error bars indicate standard deviation. ANOVA with Tukey HSD was used to determine the significant difference of experimental groups compared to the control group. statistically different groups are labeled with different letters, while groups that were not statistically significant were labeled with the same letter.

The electricity consumption was not only observed and recorded in the evening, but also throughout the day. Figure 3 compares the average electricity consumption between the no reminders, two reminders, and daily reminders groups (Figure 3). The results show no significant difference between the no reminders and the daily reminders groups ($p = 0.33$). This is not the case between the no reminders and two reminders groups, though, since a statistically significant difference was noted between the no reminder and two reminders groups ($p < 0.05$). The statistically significant difference was, however, not a decrease but an increase. This meant that the implementation of the two-reminder feedback system not only proved ineffective in reducing electricity consumption, but also led to an increase in the average electricity consumption. The results here do not align with the perceived hypothesis, which stated that implementation of daily reminders would decrease electricity consumption.

3.4. Comparison between Percentage of Lights on and Electricity Consumption, Week 1&2

Figure 4: Week 1&2 Comparison between Percentage of Lights on and Electricity Consumption (6:00 PM - 7:15 AM)

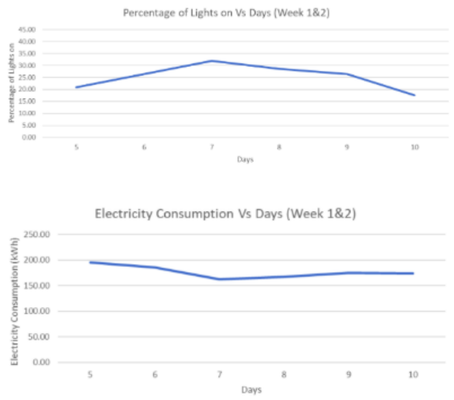

Fig. 4: Week 1&2 Comparison of Lights On vs. Electricity Consumption (6:00 PM - 7:15 AM). No reminders were sent during this period. The first four days were discarded due to the sharp increase in electricity consumption on Day 5 as a result of heating.

Figure 4 illustrates the comparison between the percentage of lights on and electricity consumption during 6:00 P.M. to 7:15 A.M. from Weeks 1 and 2. During the ten days, there were no reminders sent to the custodians. On Day 5, heating began in the school, causing a spike in electricity consumption. As a result, the first four days of data were disregarded and excluded from the figure (Figure 4). It can be inferred that the percentages of lights on do not correlate with electricity consumption, as there were no proportional changes between the respective figures (Figure 4). This indicates that lighting likely had less of a substantial impact on overall electricity consumption than previously hypothesized.

3.5. Comparison between Percentage of Lights on and Electricity Consumption, Week 3&4

Figure 5: Week 3&4 Comparison between Percentage of Lights on and Electricity Consumption (6:00 PM - 7:15 AM)

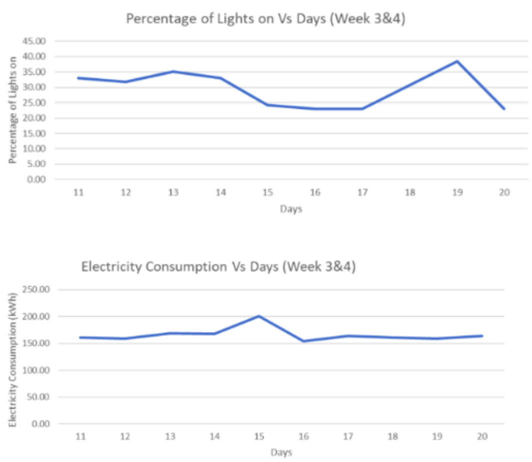

Figure 5. Week 3 & 4 comparison of lights-on percentage and electricity consumption (6:00 PM–7:15 AM). During the two weeks, two reminders were sent a week on Mondays and Fridays.

Figure 5 compares the percentage of lights on with the electricity consumption from 6:00 P.M. to 7:15 A.M. during weeks 3 and 4. From Day 11- 13, the percentage of lights on showed a slight correlation with the electricity consumption. This was seen through the corresponding decreases and increases between the lights and electricity (Figure 5). After Day 13, a large, inconsistent, spike in electricity consumption was observed. As there were no corresponding increases in percentage of lights on, it can be inferred that lights are not a major contributor of electricity consumption. Other factors most likely contribute more to electricity consumption in this time period.

3.6. Comparison between Percentage of Lights on and Electricity Consumption, Week 5&6

Figure 6: Weeks 5&6 Comparison between Percentage of Lights on and Electricity Consumption (6:00 PM to 7:15 AM)

Figure 6. Comparison of lights-on percentage and electricity consumption during 6:00 PM–7:15 AM (Weeks 5 & 6). Daily reminders were sent throughout this period. Data for Days 29 and 30 were excluded as no classes were in session due to school holidays.

The percentage of lights on and the electricity consumption from 6:00 P.M. to 7:15 A.M. is compared in Figure 6 for weeks 5 and 6. During the two week period, reminders were sent to custodians daily. Days 29 and 30 saw a noticeable decrease in electricity consumption as school holidays canceled all classes. As a result, Days 29 and 30 were removed from the figure to prevent an artificial drop in data. A slight correlation was observed between the percentage of lights on and electricity consumption, as seen on Days 23 and 27, where increases in lighting usage coincided with small spikes in electricity use (Figure 6). These findings suggest that while lighting contributes to electricity consumption, its overall impact is minor, once again indicating other factors are responsible for the majority of the energy use during this period.

3.7. Evening and All-Day Long Electricity Consumption Over Time

Figure 7: Comparison of Electricity Consumption and Different Intervals of Time

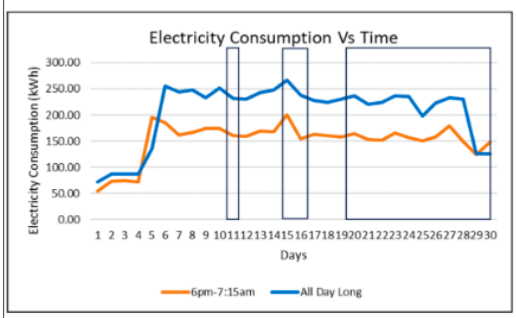

Figure 7. Weeks 1-6 comparison between the percentage of lights on and the electricity consumption during 6:00 PM to 7:15 AM and all day long. The orange line represents the time from 12:00 AM to 12:00 AM of the next day. The blue line represents the time from 6:00 PM to 7:15 AM. The boxed areas represent when the reminders were sent.

Figure 7 presents a comparison of the percentage of lights on and electricity consumption across Weeks 1 to 6, from 6:00 P.M. to 7:15 A.M. and over a full day, from 12:00 A.M. to 12:00 A.M. The orange line represents total daily electricity consumption (12:00 AM - 12:00 PM), while the blue line reflects usage during the evening and overnight hours (6:00 PM - 7:15 AM). The correlation between the two lines indicates that changes in electricity consumption during the evening and overnight period significantly influence overall daily consumption (Figure 7). This highlights the substantial contribution of evening and overnight electricity use to total energy usage. Thus, decreasing electricity consumption is best done by affecting the electricity usage from 6:00 P.M. to 7:15 A.M. Boxed areas in the figure show when reminders were sent, highlighting their potential impact on energy consumption patterns (Figure 7).

Discussion

The overall data of the study showed that giving frequent reminders may have led to a decrease in evening electricity consumption. Although a statistically significant difference was observed between the control group and the frequent reminders group, it was difficult to confirm if it was from custodian behavior since other external factors interfered with data collection regarding lights. Figure 2 suggests that there was little change regarding the amount of lights on, showing no significance with a p-value higher than 0.05. Due to these other factors, the extent to which custodian behavior was altered when daily reminders were sent is unclear. This somewhat supports our hypothesis, since daily reminders had caused a statistically significant decrease in electricity, but it is hard to confirm if the reminders were followed. The change in electricity did not align with a change in the percentage of lights on, except for the third week, which had a very slight correlation. ANOVA was used to find significant differences in the p-values. These findings suggest that it is difficult to determine if turning off the lights had a major impact on custodian behavior in a New York Public High School setting, and that these reminders might have had an indirect impact. In Figure 7, evening and overall electricity consumption were compared over the 30 days of the experiment. The data showed that changes in electricity consumption overnight correlated to changes in the total electricity consumption of the day. In addition, the electricity usage during evenings made up a significant portion of the total electricity used in the entire day meaning that a change in the electricity consumption during the evening may lead to a considerable change in the overall electricity usage. It was hypothesized that the discrepancy between the lack of a significant difference in the lights and the considerable difference in the electricity consumption could also be in part because of how the custodians might have become more vigilant of their actions and the surroundings when cleaning the classrooms. For instance, the computers in the computer room or the smartboards in the room might have been noticed as well and were turned off along with the lights. Reminders to perform these actions might have also been distributed along with the reminders to turn off the lights of the classroom. The reminder to turn off the lights might have also been extended to other rooms within the school, including the teacher's lounge, the principal's office, or other areas. In addition, the reminders may have created a culture and increased awareness of conserving electricity among staff, leading to less electricity usage.

4.2. Limitations

During this study, several factors may have influenced the results of this experiment. The duration of the experiment was conducted during several school holidays, which were not included in the data. These holidays would cause various gaps in the study, as seen from the missing days on Days 29 and 30. This caused inaccurate data as the electricity consumption was significantly lower due to almost no faculty/students being in the building. To compensate for such gaps, the duration of the experiment could be extended in future experiments. When the lights inside the classrooms were inspected, students and faculty were already present, which means that some classrooms might have been turned on before data collection. This could cause inaccuracy in reminders collecting (Table 2). To avoid this, the experiment could begin at an earlier time, before the arrival of students and faculty. The time of day at which the data was collected might contribute to the accuracy when inspecting classrooms since human error needs to be taken into consideration. To handle this issue, the individuals who are inspecting the classroom lights could sleep at an earlier time. Furthermore, night activities have been conducted within the school, which could have made the reminders less effective since lights may have been turned back on. For this reason, specifically, permission was not granted to inspect the lights after the school day was over. To address this issue, further information on the night activities could be collected and considered when implementing reminders and observing the collected data. Additionally, there was no way of confirming that the supervisor told the custodians to turn off the lights. To handle this issue, the supervisor can be asked regularly to ensure that the reminders are distributed at the appropriate times. There was also no method to confirm if the custodians followed the reminders that were distributed or if the reminders were distributed by the supervisors. This potentially contributed to the difficulties previously mentioned regarding the cause of the electricity reduction. To handle this, custodians who received the reminder can be asked if any actions were taken to turn off the lights through email messages or a survey. However, there is no way of confirming if the custodians would tell the truth in these emails or surveys, showing another limitation. There was also confusion regarding the rooms that should be inspected during the study. To handle this issue, there could be a more detailed review of what rooms in the school should be inspected before beginning the experiment. Seasonal factors such as the temperature might also influence electricity expenditure, causing abnormal spikes in electricity usage. For example, at the beginning of the experiment, the temperature started to get cold, causing the school to turn on heating creating huge spikes in electricity usage. These huge spikes would cause inaccuracy in the electricity usage as heating had caused a huge gap between Days 3 and 5. Due to these seasonal changes, some data from Figures 2 and 4 had to be removed due to a diastatic gap, which can be seen in Figure 7. Days 1-4 had to be removed due to the implementation of heating on Day 5 of the experiment. Day 29 and 30 were removed due to school holidays when no classes were in session. To avoid this, the experiment can start at the beginning or end of a season, such as the beginning of fall or the end of spring, which could help account for these abnormal spikes. In addition, it is difficult to conduct further trials to determine whether the results found were accurate. For instance, it was difficult to conduct a second trial since the behavior of the custodians could have been permanently altered, meaning that the initial conditions of the study would be difficult to replicate. To resolve this issue, future studies could explore different schools and observe results obtained from these schools. These studies could also determine if the implementation of energy-efficient behavior reminders led to the results obtained in this study. Future studies can address this by exploring the effects of these reminders in different schools with similar conditions.

4.3. Future studies

Future studies could include the effects of energy-efficient behavior reminders on electricity consumption when turning off electronic devices such as smart boards or computers at the end of the day. For example, the experiment could have the same methodology as this experiment but instead of collecting the number of lights that were on or off, it would collect the amount of computers and smartboards that were on or off at the beginning of the day. Additionally, the effect of energy-efficient behavior reminders on electricity consumption when using air conditioners in classrooms could also be explored. For example, the experiment could have the same methodology as this experiment but instead of collecting the amount of lights that were on or off, it would collect the usage of air conditioner/heating throughout the day. This can be collected through a Google form where it asks teachers whether the AC or heating was used during each period/day. Furthermore, research could also investigate how reminders would affect the electricity consumption and amount of lights off over a longer duration of time. The methodology will be the same but instead of having 2 months per trial, it can range from 4 months to 12 months per trial. However, there will be many seasonal factors that may affect the results. In addition, future research could investigate why the behavioral reminders appeared to reduce overall electricity consumption without clearly influencing custodian behavior. This discrepancy raises questions about whether other factors, such as increased student or staff awareness, contributed to the observed reduction. To better understand the custodians' role and perspective, future studies should consider conducting structured interviews with custodians both before and after the intervention. These interviews could provide valuable insight into their awareness of the reminders, their interpretation of the instructions, and any challenges they faced in implementing energy-saving behaviors.

Conclusion

Figure 1 showed a p-value between the daily reminder and the control group of less than 0.05, suggesting that daily reminders resulted in a statistically significant reduction in electricity usage. When the p-value is lower than 0.05 among all experimental groups, it means that the data is significantly different from each other. If the p-value is higher than 0.05 among all experimental groups, then the data is similar to each other. In Figure 2, it was found that the use of reminders did not affect custodian behavior. Figure 3 demonstrated that when infrequent reminders were sent, there was a statistically significant increase in everyday electricity consumption. This may be attributed to an external factor. In Figures 4 and 5, it was found that the amount of lights remained relatively consistent and had little effect on the total electricity consumption, further supporting that lights do not play a major role in electricity consumption. In Figure 6, it was found that there was a slight correlation between the amount of lights on and the average electricity consumption, meaning that when daily reminders to turn off the lights are implemented, electricity consumption can be decreased. Due to the small changes observed in the electricity consumption compared to the change in the lights, any effects on the lights likely had minimal effects on the overall usage of electricity. Figure 7 is an accumulation of all the electricity consumption throughout each day of the experiment, which compares the electricity consumption overnight to the whole day. It was found that changes in electricity consumption overnight correlated to the changes in electricity consumption throughout the whole day and made up a large amount of the total electricity used during the whole day, meaning that any changes affecting electricity use overnight might have similar and meaningful effects on the overall electricity usage. Based on these conclusions, it seems that reminders had an indirect effect on electricity consumption. Due to the possibility of a false positive, this study should be conducted in different schools of similar sizes and populations to determine if the relationship between reminders and electricity consumption is genuine.

Acknowledgements

We thank Dr. D. Marmor, Mrs. N. Jaipershad, Dr. L. Wang, Dr. B.A.B. Blackwell, Dr. J. Cohen, Dr. S. Lin, Mr. Z. Liang, Mrs. C. Rastetter, Ms. Amy and Ms. DePietro and the FLHS Science Research Program.

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