# **Introducing principles of environmental comfort and control to support energy conservation in education buildings:**

Project-based learning approach

by


Mahboobeh Keshavarz

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Approved by:

Major Professor
Prof. Michael Gibson

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# Abstract

The construction of green schools in the U.S. has considerably soared in recent years. Sustainably designed schools come from not only energy savings, but also from wide-ranging, measurable student health and performance benefits associated with natural light and improved environmental quality. The flip side of sustainable buildings, however, is that technology and controls introduce a new level of complexity compared to conventional buildings. Building owners and occupants find it very difficult to navigate these controls. This results in an increase in energy expenditure of the buildings, while users fail to appreciate their environmental comfort. Therefore, education on environmental comfort in spaces and identifying building controls seems of great significance. By the same token, decisions made with regard to the operation of the controls by building users need special attention as it is directly related to energy saving.

This study investigates the effect of Project-based Learning on increasing the knowledge level and changing attitudes and actions of green building occupants to conserve energy. Project-based Learning is an educational method where individuals are required to learn and apply the concepts through experience. Using this method enables building users to find answers to the real-world problems by testing their ideas while working in groups. This learning approach has also the capability to translate into changes in building users' attitudes and actions related to energy conservation. To study the effect of this learning approach, data was collected from a total of 119 students from APD design community (Seaton and Regnier—newly constructed green school) at Kansas State University. A pre-knowledge survey was conducted initially to capture the general knowledge of the participants about comfort and controls. For the experiment, a series of class lectures and activities were devised to which students, based on the group they were categorized in, were exposed. The students for this study were grouped under three categories: 1) Traditional

Learning group (control group) in which students required to only watch class lectures, 2) Individual Project-based Learning group in which students had to complete a series of individual class activities in addition to the tasks assigned to the control group, and 3) Peer Project-based Learning group in which students were asked to do peer-to-peer interaction for the class activities in addition to the tasks assigned to the other groups. After the experiment concluded, a follow-up survey was conducted to evaluate the impact of the activities on the improvements in knowledge and controls' operation level of participants based on students' self-report.

By analyzing the results from the experiment, this study identifies that the groups that have received Project-based Learning module, generally, have used building lighting and dimming controls more than the control group. Particularly, the Peer PBL group was identified to be the group with significant change in knowledge level in this study. Class activities and peer interaction have highly affected students' perspective towards energy savings and environmental satisfaction. Findings from the experiment confirmed that peers were recognized to be extremely influential in raising participants' awareness and motivation towards operation of the controls, energy conservation, and environmental comfort.

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# Chapter 1- Introduction

## Background

Climate change from greenhouse gas emissions is a huge problem. Evidence shows that a large portion of greenhouse emissions is attributable to buildings caused by the heating, ventilation, air conditioning, lighting, and equipment, all of which use fossil fuels [1, 2]. This, in fact, has led designers and owners to find innovative design strategies to address energy concerns that are responsible for $CO_2$ emissions. As a result, the notion of the green buildings emerged. Green buildings, by definition, refer to buildings that apply different design strategies that are "environmentally responsible and resource-efficient throughout their life-cycles" [3]. Among green building types, green schools are among the fastest and most demanding markets nationwide. As a matter of fact, sustainable schools not only help the building owners reduce energy expenditures, but also improve learning performance and health through measures like natural light and environmental quality [4–6]. These outcomes benefit students and teachers and not just the bottom line of school districts [7].

## Problem statement

Despite the advanced strategies used in green buildings today, there are still reports from building owners that energy conservation targets are not always fully realized in these buildings and operational costs are still high [8, 9]. For instance, a study done by Brown et al. [9] in Toronto looked at four LEED gold high-rises and found that one of the major hindrances to occupant satisfaction and energy saving was "frustration and/or confusion" with building technologies. A conceivable explanation for this concern is that green building control systems -- such as HVAC, lighting, and dimming controls -- operate differently than those of conventional buildings. In fact, in the most advanced green buildings, systems use automation extensively; yet it is still common for green buildings to have some reliance on users. In green buildings, technology and controls themselves may be blamed for creating such complexity and confusion for building occupants and owners to navigate. This, unfortunately, has led building occupants and owners to neglect building controls, resulting in an unfavorably high energy consumption level and the failure of the original design intentions for the green building. A basic education is required for the building occupants to understand the decisions they make regarding how, when, and why to use the controls, resulting in increased success with energy conservation and satisfaction with environmental comfort. Because of their limited comprehension of the comfort factors, the occupants of the building are not always fully aware that they can adjust discomforting factors within their environment. An exemplar of such scenario is when occupants put their computer screens in the direction of the glare caused by the daylight or lighting fixtures without noticing the discomfort it creates for their vision in the long run, such as eye fatigue or aging. Another comfort-related issue example is that a vast majority of people do not realize that the human body acclimates (or gets used) to the ambient thermal conditions after their prolonged stay in the space. The aforementioned are merely a few of many examples, emphasizing the absolute necessity of basic education regarding controls and comfort.

Educational settings such as schools are a good place to begin with as they are perceived as the cornerstone for cultivating environmental concepts, stressing the fundamental sciences along with the positive peer influence, which have the potential to develop good life-long habits. It is also noteworthy to mention that schools provide students the opportunity to respond to hands-on learning where context in the real world is captured. More importantly, students are in their key behavioral development period.

In a preceding study, “Stewards in the Classroom: Introducing Principles of Environmental Comfort and Control to Support Energy Conservation in Education Buildings” [10], here referred to as phase one, a number of educational methods to educate building occupants about issues related to environmental comfort and controls were evaluated. The settings for this research were Seaton and Regnier Halls, newly constructed educational buildings at Kansas State University that achieved LEED Platinum in 2017. The study concluded that basic education in comfort, building control usage, and informed decision-making improved the prospect of energy conserving behavior by building occupants, while leading to better appreciation of the quality of their learning spaces.

In the interpretation of results and observations from phase one, various theories of human cognitive behavior were investigated, with an emphasis on three important factors (AMA): 1) awareness, 2) motivation, and 3) actions of the users. Looking more carefully at cognitive behavior helped shed light on the following research questions from this earlier phase of research: What helps building users increase their awareness and become knowledgeable of their environmental comfort and controls in the building? What are the motivational factors that are helpful in encouraging building users to save energy and know their environmental comfort? Lasty, how do building occupants improve decisions regarding the controls, in order to save energy and improve comfort? (Fig. 1-3)

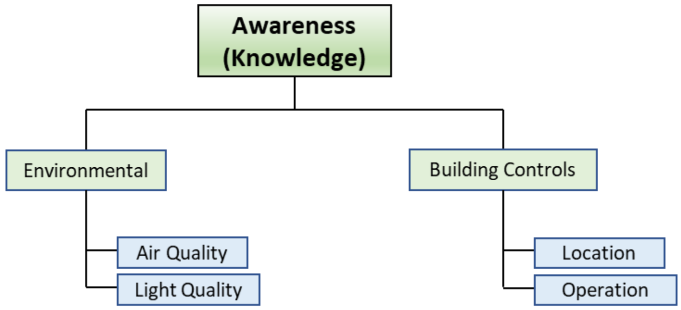


**Figure 1**. Occupants’ environmental and controls awareness categories.

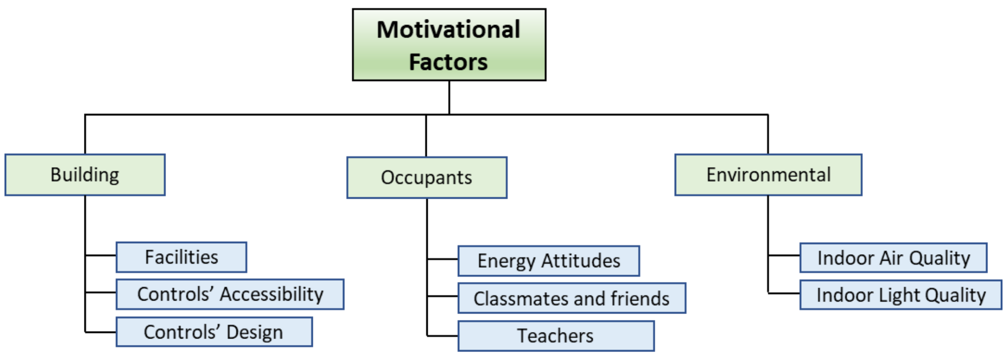


**Figure 2**. Motivational factors that may result in an action by occupants.

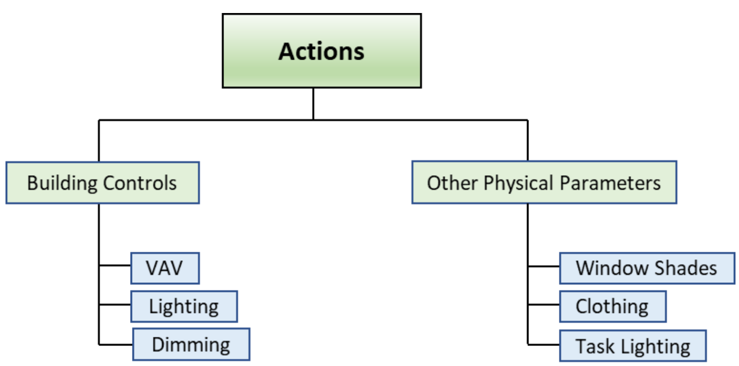


**Figure 3**. Actions taken by building occupants when needed.

By educating building users, it was theorized that improvement would be observable in their awareness, motivation, and actions with regard to energy conservation. Two educational methods were compared in this phase: 1) direct engagement, and 2) passive information displays in which users were given access to the information alone. Subsequently, the motivation and knowledge of users about the environmental comfort criteria and operation of the building controls was then examined between the two education methods used.

Five studios from APDesign community were selected for the experiment in this phase, one of which was designated as a control group. The utilization of lighting controls and window shades in each studio were monitored before, during, and after the interventions. Passive information displays consisting of one energy dashboard, an electronic display that shows energy consumption in real-time, and a wall-mounted poster calling attention to the lighting controls and reminding users about the importance of energy savings, were placed into two studios. Another two studios received an intervention focused on direct engagement with the user group. One of the researchers visited these studios and gave a presentation regarding thermal comfort issues, different methods of adaptation to environmental discomfort, and how to appropriately apply the building controls with respect to comfort and energy conservation. A follow-up survey asked the users what factors led them to take action towards energy conservation. The follow-up survey questions given to the control group mostly focused on whether users in the studio even noticed the presence of the meters located near the windows, around the desk area, and at the center of the studio. If so, control group members were asked how much these meters genuinely influenced users to locate the controls and ultimately use them. However, for the other four studios which received direct engagement and passive display interventions, the follow-up survey evaluated the influence of the meters on the action levels of the students, presuming that the students noticed the presence of the meters a priori.

Results from the experiment suggested that a change in the behavior of building users is possible through education. Direct engagement with the users was the most effective approach. Additionally, peers were later identified as a significant factor in motivating the students to take pro-environmental actions which resulted in increased use of the controls and decreased utilization of electricity.

Knowing that the interactive approach resulted in less electricity consumption in the studios that received this experimental intervention, phase II of this study will evaluate the impact a specific learning method has on peer influence and decision-making of the building users when it comes to building control usage, energy savings, and comfort.

**Purpose of the study**

Nearly every student will eventually be a building owner or a building occupant whose decisions impact resource consumption in buildings. If a more complete understanding of comfort and control is critical to the operation of tomorrow's green buildings, then engaging students in this topic will increase the likelihood of this knowledge having a broad future impact on society. The field of education has long studied various methods of learning whose outcomes turn basic knowledge into meaningful action. Since Locke's 'Empty Vessel Theory' became challenged by modern theories of learning, it is increasingly clear that raw facts and knowledge alone do not constitute learning [11]. Similarly, just passing off information to building users about controls is not going to cultivate meaningful use of those controls, and certainly will not be an effective way to encourage energy efficiency. Theories of active learning suggest that "learning by doing" results in a greatly improved learning process and gives the learner a ready connection between knowledge and the world [12]. In this research, Project-based Learning (PBL) was adopted because it addresses key points from the earlier ‘stewards’ study from phase one, including the role of peer and applied knowledge.

Additionally, using this educational method will lead us to the better evaluations of the following:

- Understanding the criteria affecting environmental comfort in the spaces.
- Identifying the building controls that contribute to environmental comfort.
- Describing how changes in each building control affects energy consumption.
- Efficiently making decisions in using of the controls installed in the building.

It is hypothesized that if students or occupants are engaged in a project which requires them to “learn by doing” while working in a team, their self-reported behavior toward resource conservation will be improved substantially [13]. This learning method can support sustainable design goals in schools, ensuring energy is saved while the user better appreciates the environmental quality of the classroom and learn basic principles about building science and energy use. Moreover, introducing students to a comfort-based approach to building energy efficiency and sustainability through the PLB method will lay the foundation for increased stewardship of students’ environments. Classrooms are environments where students relate and apply this knowledge; yet this knowledge also stands to shape the way these students inhabit their future living and working environments.

Thus, the current research proceeds with these questions in mind: 1) How successful will the PBL module be in delivering the information to the users and increasing their awareness, motivating them, and eventually influencing them to take actions towards resource conservation? 2) How influential will the peers be in this process, and can peers effectively reinforce the information diffused to others and to change or improve behaviors?

It is hoped that the application and study of the PBL method in this research will be adapted into future work with K-12 communities. These learning communities can be educated in the formative periods of development about how, when, and why to use the building controls not only in the immediate classroom environment, but in the homes and future workplaces. By engaging building users when they are students, the framework for energy-conserving decision-making and habits can be established. By doing so, these building users will not just be mindless occupants. Instead, they can be better-informed, active stewards of the buildings they spend time in, more fully realizing their responsibility in energy resourcefulness.

# Chapter 2 – Project-based Learning (PBL)

We live in a new era of knowledge wherein a drowning in information and technology seems inevitable. We tend to use technology so routinely that we have almost forgotten the impacts of our decisions, especially the distant ones, on our surroundings. This issue has gained more significance in recent years, as clearly, we are now more used to and reliant on technology than centuries ago. Steve Matthewman, along with some other social theorists, believes that technology and humans have a strong mutual relationship. One can affect and drive the other one, and vice versa [14]. Human beings develop and utilize technology to answer to their needs. Technology, in return, affects human beings' behavior by transforming difficult tasks to much easier and less time-consuming ones. However, the big problem arises when individuals undermine the proper use of certain technology to address their needs and do not acknowledge it anymore. This serious issue has been often observed in the individuals' behavior in smart buildings. The building controls are smartly designed for the users to respond to their environmental needs, but they do not see it as fascinating as they see their smart phones or other technological devices.

Inspired by such an observation, we have conceptualized and devised an approach using Project-based Learning to quantitatively evaluate how a spark in awareness, motivation, and action of the building users leads to energy conservation in green-education buildings while users feel comfortable environmentally in their space. In the following, we will elaborate more on this educational method and its associate advantages.

Obviously, individuals attend schools and colleges to become knowledgeable about specific subjects, learn new concepts, engage with new information, and find potential answers to their questions. However, it is crucial that these concepts and ideas are conveyed in schools in a way that students genuinely learn them. In the education system, various methods of teaching are currently available, and each has its own application depending on the context. But how successful are these various methods in conveying the meaning and application of knowledge in the real world? How effective are learning methods in capturing individuals' attention about the subjects and putting that knowledge into practice in the real world? One particularly successful educational method, called Project-based Learning, has responded to these aforementioned questions about how to convert knowledge into real world actions and insights.

**What is Project Based Learning?**

Project Based Learning (PBL) or Active Learning, first proposed by John Dewey in the 20$^{th}$ century, is a teaching approach where students actively find solutions to real-life problems by experiencing and testing ideas in groups of peers [15]. Project-based Learning creates a constructive learning atmosphere in which knowledge and methods of dealing with problems are shaped and evaluated. In this method, according to Chickering and Gamson, students do more than just listen and write; they are involved and responsible in finding solutions to the problems they study [16]. In the PBL approach, students are required to critically think about the subject and analyze possible solutions in order to choose the most appropriate one.

Using this learning method can be very engaging in classroom environments. First and foremost, it requires students to work in groups and exchange their thoughts and ideas with one and another [17]. Working and communicating with peers supports student cooperation and management skills. Secondly, it allows students to "learn by doing" and directly experience testing of ideas or concepts in the projects and taking responsibility for their decisions [18]. This model reinforces students' ability to link what knowledge they have acquired to real-world issues and improve their problem-solving skill. Another remarkable aspect of PBL is that it gives students the opportunity to increase their self-direction and motivation towards the project and learning process, as a result of their involvement in groups [19]. In fact, the freedom and challenges that students experience and face while resolving problems in projects can turn them into a more highly engaged individual [20].

The PBL method offers advantages to teachers as well, because students' teamwork helps to adapt the range of creativity in solving problems, skill they use to find solutions, and knowledge among different students, giving teachers a better way to communicate. For the research explored here, the diffusion of knowledge poses the problem of how to ensure that ideas and concepts are effectively exchanged withing the group. The PBL method creates a scenario where students take an active role in diffusing knowledge, overcoming the obstacles posed by working with a group of students whose attitudes about environmentally conscious behavior may be very different.

In traditional learning approaches, it is usually the teachers who are the 'sage on the stage' and control the class environment. It is essential to understand what to do with knowledge and how and why to apply it. The 'sage on the stage' paradigm is a poor approach to perform this because it assumes the information has some kind of authority. It is noteworthy to mention that information alone will not have much influence on behavior or perspective of the world as we witnessed it in our study in phase one.

However, in PBL, it is totally the opposite because the information is accessible, but teachers are facilitators in a process in which the students take the lead [21]. When students are engaging each other in problem solving, they go more deeply into the problem and become critical thinkers. This can lead to a real change in perspective and behavior towards the materials or the concepts they study.

The advantages of PBL make it an excellent framework for introducing students to the difficult and multifaceted problems of environmental studies. For example, Genc used this learning technique in a school to evaluate the attitudes of students about environmental problems in a course called "Environmental Education" [22]. In this 14-week course, students were first informed about some basic environmental issues and then asked to work in groups, gather information, and work collaboratively to solve real-world problems. The project topics mainly focused on environmental dilemmas such as global warming, ozone layer destruction, soil destruction, etc. To gather information and data, students used a variety of approaches such as interviewing people who lived in the areas that experienced environmental pollution, government agencies, etc. After that, students had to determine the possible solutions through brainstorming over the observed environmental problems, estimate a project budget required for dealing with such problems, and finalize a report in which the solutions are described. The final step was to give a presentation about their findings to the whole class. The follow-up survey results showed that this teaching technique was beneficial for students, encouraging them to deeply understand, change their attitudes, and become creative and critical thinkers towards environmental problems. Also, students' reports revealed that this teaching module has the capacity inspire long-term learning and sharing of their new perspectives with their families.

Another study done by Kaldi et al. examined the effectiveness of the PBL method on primary school pupils during a 12-week study named "sea animals," in which they had to study topics such as anatomy, associated food, types, and area of specific sea animals [23]. In this study the researchers sought to evaluate the knowledge and attitudes of students towards "self-efficacy and task value," by being involved in groups and presenting their findings to peers [23]. Students for this study, in order to experience and gather information, had primary and secondary source options. Primary sources included doing research, field-based visits, and talking to the experts. Secondary sources included reading books and magazines, watching DVDs, and playing games. During the process, students had the chance to share their findings with their peers and the whole class. The quantitative results from this study suggested that pupils expanded their knowledge towards the 'sea animal subject' by being actively involved in the project and getting help from their teammates. Additionally, based on the qualitative results, this teaching approach allowed pupils to value group study more than traditional methods requiring students to learn and work individually. Later, pupils' reports demonstrated that they were able to better understand and comprehend the subject compared to learning from their textbooks. Similar studies done by different researchers confirm the above findings [24–26].

In the context of energy conservation and environmental protection, Pisupati et al. developed a 3-credit general education course associated with energy savings and environmental protections for non-technical students using PBL method [27]. By emphasizing active learning, the main purpose of this course, was to introduce students to the concept of energy conservation on daily basis, saving resources, and money while protecting the environment. The other objective of this project was to study the effect of individual projects versus group projects on the students' level of learning. For this class, students had to work on four different environmental protection projects by conducting hands-on experiments and writing down their reports after a few lectures were given by the teacher. Projects primarily focused on household appliance selection, automobiles, water heating savings, and dormitory energy savings. Students were required to work both individually and in groups of four to share their information, data, and findings with their peers. For each project, whether done individually or in groups, students were required to write reports, observations, analyses, and possibly conclusions. Results from the students' reports later demonstrated that this method of learning while working in groups was very successful in growing their knowledge about environmental issues and energy consumption compared to traditional approaches. Discussions with students also revealed that this learning module was successful because "there is a great deal of enthusiasm for relating knowledge to real applications that they may actually use" [27].

**PBL and reflective learning**

Another imperative component of the PBL approach is called 'reflection,' which enables students to turn their experiences into learning by reflecting on them. Reflective learning, by definition, is "a form of education in which students reflect upon their learning experiences" [28]. According to John Dewey, "we do not learn from experience specifically, we learn from reflecting on our own experience" [13].

Having said that, this teaching model compels students to ask themselves a series of questions related to: 1) How does the subject fit into what I already know? 2) Are there any parts of learning that I do not understand? 3) What are the components that I must try next? Another part of reflective learning focuses on how learned knowledge is linked to the social context and past experience of the learner. In this part, an individual may ask him/herself: 1) How does this subject that I have learned affect my earlier understanding? 2) How does what I have learned from this subject relate to my own experiences? [17]

Additionally, reflective learning enables students and teachers to identify obstacles to learning and consistently review and critique what they have learned [17]. Several studies demonstrate the profound role that reflection plays in the PBL method [17, 29, 30]. Based on these studies, it is essential that students in their learning procedure increase their capacity to self-direct through reflection and self-assessment while they are working on the projects. A study done by Mason and Singh demonstrated how the lack of reflection and self-monitoring by physics students in a quantum mechanics course led them to perform more poorly on a final exam that included the same questions from the mid-term [31]. In a similar study conducted by Scott et al. at the University of Illinois Urbana Champion, a group of students who enrolled in a calculus-based course were the subjects of an investigation of reflective learning method and its related impacts on students. According to the researchers, results from the interventions support that “through reflective learning, students would recognize the concepts and physical principles across different contexts more easily than without reflection” [32].

In architectural education, reflective learning and PBL methods together have an important role as well. For instance, in 1980 Donald Schon suggested that teaching design studio in architecture allows students to reflect upon their actions and evaluate better their own practices [33]. To put it another way, critical reflection is built into the essence of design studio learning process where students not only can reflect upon their own work, but also upon the work of their classmates. Schon also asserts that the use of the reflective learning approach in architecture studio is critical to the development of students’ learning and understanding of their own practice.

The Buck Institute for Education (PBL WORKS) evaluates many of the projects using PBL method, and has recently emphasized on the importance of students’ reflections in learning process [17]. Buck researchers believe that it is crucial that teachers plan for students’ reflection throughout the project. In one of their articles “PBL in the Mirror,” they explain, for instance, how much more effectively medical interns can learn new concepts and recognize patient disease if they learn how to reflect upon their observations and experiences. It is also important to note that reflective thinking may go unnoticed in everyday life; but in structured academic modules, it is usually part of a specific activity such as focus group discussions, surveys, whole class discussion, checklists, etc. In the “PBL in the Mirror” study, once the projects or tasks are completed, students can “look into the mirror and reflect on their experience as a whole”. Reflection is a unique component of the PBL module where students can relate their past experience, recognize relationships to the real world, and link those relationships with new ones. To put it another way, reflection guides students to make sense of situations and solve problems by critically reflecting upon or recalling their experiences. According to Dewey, reflection lets learners “explore why things turned out the way they did and what possible actions could have given a different outcome” [34].

Another project done by Carrie Snyder-Renfro, entitled “The Students Rebuild Hunger Challenge”, followed the influence of Buck Institute for Education, demonstrates how the use of reflective learning was constructive and educational for students [35]. In this project, students had to discuss, share, and listen to each other in a restorative circle meeting regarding issues of hunger and malnutrition in the world, especially in the city in which they live. She believes that restorative circle sessions let students be heard equally and seeing each other’s faces gives them insight into one another’s emotions. Snyder-Renfro intentionally selected this topic due to the rate of the hunger in the city they live. She wanted to see why some people, even with availability of the food pantries in the city, still do not take any food. She thought there might be possible reasons to this question and students could be helpful in finding answers. According to Snyder-Renfro, the goal of these sessions “was not to solve anyone’s problems, but to share and affirm or appreciate the thoughts of others.” The outcome from the sessions seemed to be very influential and she believes that students’ reflections helped in understanding better the problem from different angles. This specific PBL study is similar to our research study in which we do not have an obvious answer as to why building users in green buildings do not clearly notice the connection between their actions towards controls and energy saving targets. There might be no valid answers to such questions because they are sometimes difficult to analyze, but it is yet another way for us to perceive how green building occupants view problems like this differently.

**Peer Influence**

Robert Frank, in his book ‘Under the Influence’, explains how environments are able to encourage smoking, bullying, tax cheating, wasteful energy use, and etc. [36]. He believes that what we do most of the time is because our neighbors, friends, peers, or favorite celebrities are doing it. In other words, we are influenced or pressured by our friends, neighbors, peers, or people around us to perform actions under specific situations. However, it is believed that there is a difference between peer pressure and peer influence [37]. Peer pressure is a forcible action caused by ones’ peers that leads them to take actions which normally ends up in changing their behaviors in a negative way. Peer influence, on the other hand, is a persuading or influencing action from peers causing individuals to become persuaded or encouraged to take specific actions or behave differently from what they normally do. Peer influence mainly emphasizes the positive sides of the actions: actions that are beneficial for individuals and their surroundings. In this research, since we are focusing on the importance and power of PBL and working in teams is one of its most important features, we assume that the role of the peers in the groups can reinforce and increase awareness, motivation, and actions of individuals towards energy conservation, comfort, and controls. In order to be listened to or accepted, peers in PBL module need to have at least some of the following characteristics [38]:

- They must have common beliefs and interests with others.
- They must have strong communication skills.

- They must be at the same age level with others.
- They must be friendly.
- They must have equal level of knowledge.

Several theories related to peers and their associate characteristics have been proposed by the scholars. For instance, Frank in 'Under the Influence' also refers to peer influence as a Behavioral Contagion, which was first proposed by Gustave Le Bon [36, 39]. Behavioral Contagion is a type of social influence that explains why a person copies a certain behavior of others who are near him/her or to whom they have been exposed. In the PBL technique, since peers are at the same age, typically have the same knowledge rate, and are commonly in contact with each other, it is very likely that they simply copy each other's behavior without giving it a second thought.

Another theory, which parallels behavioral contagion theory, is called Social Learning or Observational Learning developed by Bandura. In this theory, individuals' behaviors can be shaped through observation of others' behaviors under a given situation [40]. Since learning is considered as a cognitive process and can occur in a social context, simply by imitating others' behaviors, individuals are prone to be influenced and change their behaviors. Following this theory, Abrahamse and Steg have investigated the impacts of different social influence approaches through a meta-analysis comparison on resource conservation. Findings from their studies suggest the effectiveness and powerfulness of the social influence compared to the control groups [41]. Likewise, Henry Tajfel and John Turner the founder of the Social Identity theory, assert that individuals' actions are highly dependent on their social identity; meaning that the more they have ties among their social groups, the more they will take actions due to their feeling of belonging to those groups [42, 43]. This tightness within groups gives individuals a positive self-image within their groups, which results in more actions and changes in behaviors and attitudes. Social Identity Theory can describe the characteristics of the school environments. Classrooms are environments where students may feel connected to each other, probably considering themselves as a family or a clan [44]. Therefore, it is reasonable to conclude that Social Identity Theory can provide motivation for students to take actions and be responsible for their behaviors.

Several studies associated with the above-mentioned theories were conducted. For example, Carrico and Rimer have evaluated the influence of peer education on energy conservation in the workplace. In this study, they concluded that by changing employees' behavior in the workplace through peer education, the energy consumption rate was decreased significantly. In this study, peer educators had to disseminate the information among their colleagues and encourage them to save more energy in the buildings. When compared to the control group, results indicated that the groups that received peer intervention had a significant reduction in energy consumption [45]. Furthermore, in a study done by Paluck et al. on collective norms and harassment behavior in a school in Connecticut, researchers confirmed the influence of the peers among students in decreasing the rate of the harassment [46]. In this research, they believe by changing the behavior of students through what they call "social referents" or peers, the rate of the harassments in the school reduced significantly. For this study, they selected students who had been harassed or bullied in the school by their classmates and asked them to talk about the drama and tragedy they had experienced, either in an essay addressed to their peers or through direct communication. In this research, these social referents' main goal was to interact with and influence their peers' perceptions of collective norms by daily direct communication. Similarly, results suggested that the influence of the peers on rates of school harassment had been so pronounced that, subsequently, no reports were given by the school authorities after this study.

Following Bandura's Social Learning or Observational Learning theory, Darby in her research measured the significance of learning through observation in a village that had won a competition for the most "energy-conscious" village in Oxfordshire. In this study, she showed that one of the key factors for energy conservation for this village was social learning that influenced individuals to act [47].

While countless studies were successful in the assessment of PBL techniques and their effectiveness on student learning in classroom activities, there is no empirical research done that studied PBL employed around the topics of environmental comfort, usage of the building controls, and resource conservation in green buildings. It is our mission in this study to deploy and measure Project-based Learning in school environments in order to acquaint students with the concepts of environmental comfort, adaptation strategies, and usage of building controls. The advantages of PBL techniques are expected to translate into changes in attitudes and actions related to energy conservation that will potentially be long-lasting. Plus, by educating students through PBL method, it is likely that students will share their new knowledge with parents and family, sharing perspectives about controls, comfort, and energy savings in their homes. Surely, these are all key factors that make occupants more knowledgeable about energy conservation and responsible behavior and decision-making, which can drive buildings -- including green ones -- to perform at their best.

# Chapter 3 – Materials and methods

Initially, it was intended to conduct the experiment similarly to phase one of the study, in which the environmental measurements such as electricity and window shades recorded utilizations were taken before, during, and after each intervention. However, due to COVID-19, a considerable amount of experimental setup for this study had to be changed. First, building users were required to follow a six-foot social distancing protocol that changed the manner of occupancy for academic buildings. New building regulations from university administration discouraged students from spending a normal amount of time in their design lab. Many classes were offered online, and some students preferred not to come to campus, participating in coursework from home. These factors required some parts of the experiment to be altered, seeking a way that the purpose of the study would not be affected. Therefore, instead of taking the studios' control utilization before, during, and after the interventions, for the new experiments it was decided to ask participants questions using surveys before and after experimental interventions. The survey-based approach seemed to be practical because it helps to capture more insight into the users' 'awareness' and 'motivation' parts of our constructed AMA process and not just the 'actions' come afterwards. In other words, this type of approach can be useful in describing and understanding the characteristics of participants in a study and know better their self- reported behavior under different conditions. Additionally, since some of the students preferred to participate in coursework primarily from home, some questions were designed to capture students' knowledge level of the comfort/controls in their home environmental as well as their studios' environment and allow responses to be compared. In the following sections, components of the experiment are discussed in further detail.

**Survey development (Pre-knowledge survey test)**

In order to measure the impact of the PBL method, it was necessary to test the general knowledge level of the participants prior to the experiment in this study. To that end, a survey[1] was drafted using Qualtrics, an automated, web-based survey platform, in which participants' awareness/knowledge, motivation, and actions were captured. The survey was named the 'pre-knowledge survey' and contained a set of questions that intended to not only capture the participants' comfort in their working space, but also how much awareness/knowledge they have towards behaviors and decisions regarding the building controls and other pro-environmental actions to deal with environmental discomfort. It is very important to mention that the data collected from the pre-knowledge survey especially related to their level of 'action' is self-report data. Due to COVID-19 restrictions, participants were requested to be honest with their responses for the pre-knowledge survey since observing and directly monitoring their behavior (mostly their actions) was no longer an option. The pre-knowledge survey contained 70 questions in total, of which 45 questions were allocated to the studio environment, 16 to the home environment, and 9 to general information.

In August 2020, the pre-knowledge survey was conducted randomly throughout 6 design studios in the APDesign community and gleaned 101 complete responses. The participants were all third-year Architecture students who enrolled in a course called 'Environmental Systems in Architecture I (ESA I)' for the fall 2020. The total number of students who enrolled in this course was 119.

[1] Data collection ethics was approved by IRB.

The pre-knowledge survey was assembled into three sections. The first section contained questions pertaining to participants' studio environment (i.e., spaces where design studios took place, where students have their own assigned desks) that allowed the users to self-report different aspects of their environmental comfort, including temperature, air movement, light adequacy for different tasks, and glare presence in their workspaces. Similarly, the second section of the survey contained questions pertaining to participants' home environment. The last section consisted of general questions asking about participants general energy conservation goals, and the role of their friends, teachers, and families in influencing them to be more responsible towards energy savings. Participants in this section were also asked to report the level of sharing knowledge with their friends and families about the proper usage of the controls at their home environment.

Each section corresponded to the awareness, motivation, and actions of the users as related to the AMA process described earlier. For instance, for awareness or knowledge in section one, participants were asked questions related to the location of the controls in the studios, such as: "Based on your familiarity with your studio, are you aware of the location of the VAV controls? (VAV controls are small plates with a slider a "+" and "-"on them that are being used to adjust temperature by +2F and -2F)." Additionally, respondents were asked about their knowledge of and their frequency in using the controls in their studios. Asking such questions intended to reveal to what degree participants are aware of the environmental controls (lighting/dimming and VAV controls) that could help them deal with the possible environmental discomfort in their studios. Knowledge of using such controls in green buildings, as mentioned earlier, is something that few individuals have. More importantly, the proper occasion for operating such controls in green buildings is something that occupants may not be aware of. Therefore, the survey posed some behavioral questions related to when and how the building controls are used or not used by the occupants. Several questions (yes/no answers) were asked about whether building users turn the lights off when they notice no one is in the studio or not. The survey also asked whether they turn the lights off if they realize that they are the last person in the studio who is leaving. The survey also sought to capture participants' actions and decisions towards the environmental discomfort they experience in their studio. Scenarios were also posed, such as: "I use a personal lamp or other light source at my desk to improve visual comfort at my desk" or "I use blankets when it is too cold in the studio." Responses for this part of the survey were designed in a five-point Likert Scale (e.g., 1- strongly agree, 2- somewhat agree, 3- neither agree nor disagree, 4- somewhat disagree, 5- strongly disagree). Usually a five-point Likert scale is most preferred by the researchers because of the variability in the response options. It, in fact, allows participants have more response latitude and not to being forced choose a specific answer [48, 49]. Another objective of this survey was to capture to what extent building users manipulate or control the window shades available in their working spaces. What circumstances and behaviors affect their choices to manipulate the window shades, which is a practical response to lighting discomfort? To better evaluate the participants' responses for this part, the survey posed some awareness questions that pertain to the light quality satisfaction of the users of their space. The users were asked to report how typically satisfied they are with the light quality of their studio; light quality was defined as when the building users can comfortably and accurately see the visual task that they are performing without interference from glare. Responses for these questions were again devised in a five-point Likert Scale. The survey also focused on how much participants believe that the window shades in the studios significantly improve the light quality of the space. A question that targets both users' environmental awareness (about the benefits of natural light) and their associate motivation (related to human health and performance) which influence them to take actions and use the window shades.

For the second section of the survey, it was aimed to assess the differences between home environmental comfort/controls versus studio environmental comfort/controls from participants' points of view. How much control participants have over the building controls at their current residences (i.e., dorms, apartment, or houses) was compared to that in the design labs (i.e., studio spaces). How much knowledge participants have regarding the operation of the building controls, such as reading thermostat set-point numbers, was compared between their homes versus studios. Regarding the utilization of controls at home, respondents were asked how frequently they manipulate the thermostat in their home.

In the last section, containing the general information, the survey introduced questions that supported more fundamental questions to evaluate participants' perception of environmental comfort/controls in different circumstances. For instance, respondents could indicate whether they use environmental controls at home or studio to conserve energy or not. Also, the survey posed questions about how much participants' friends, teachers, school, and families have been helpful in raising their awareness and educating them regarding energy conservation or usage of the environmental comfort/controls. Participants were asked to what extent they believe that enough information in Seaton or Regnier Halls is provided by university administration on how and when to use the building controls. By asking this question, this study was interested to find how much information has been diffused by the university that helps occupants locate the controls and operate them. Sometimes it is not the building users' fault that energy is not always conserved as it should be. It is, in fact, the lack information provided by building authorities that makes users seem to be less cautious and motivated in terms of resource savings.

Moreover, survey respondents were asked to what extent they share their knowledge and understanding of the environmental comfort/controls with their friends, classmates, and families.

These questions were designed prior to experimental interventions to capture the role of the teacher and peers in education of the students and diffusion of the information (Table 1).

**Table 1**. An overview of information asked from participants in the pre-knowledge survey.

| | Section 1 **(Studio Environment)** | Section 2 **(Home Environment)** | Section 3 **(General Information)** |
|---|---|---|---|
| Environmental comfort and controls awareness | Controls' locations and operation knowledge<br>Studio air and light quality<br>Controls' operation when no one in or a few individuals are in the studio. | Controls' locations and operation knowledge<br>Home air and light quality | Energy conservation goal<br>Information regarding controls' location and usage from school administration |
| Motivational factors | Darkness, Brightness, Glare, Daylight, Privacy, Classmate, Teachers | Darkness, Brightness, Glare, Daylight, Utility bills | Classmates', families', friends', and school's influence on the controls' usage |
| Actions taken | Frequency usage of the controls<br>Actions taken to deal with possible environmental discomfort | Frequency usage of the controls<br>Actions taken to deal with possible environmental discomfort | Level of sharing knowledge regarding environmental controls and comfort with families and friends |

## Intervention materials

To apply the concept of Project-based Learning (PBL) in educating building users, an experiment was devised in which six design studio classes were selected as the study groups. The educational interventions that were used in this study developed under three categories:

- The **Traditional Learning Module** represented the traditional learning approaches in which students only listen to the teacher in the class. For this group, the teacher addressed students with a prepared lecture, called 'comfort' lecture. In this lecture, environmental comfort was characterized into distinct parameters which can be used to predict comfort and discomfort in a space. The comfort lecture consisted of two separated lectures, thermal comfort and visual comfort. Since most of the lectures were conducted online due to the pandemic, class lectures were recorded and accessed on-demand through online courseware. In week one of the experiment, students for this group were required to watch the thermal comfort lecture and in week two, the visual comfort lecture. Following the lectures, students were assigned a lab assignment which was not related to the materials discussed in comfort lecture but covered other topics of the class instead. For this intervention group, the total number of students was 39.

- The **Individual Project-based Learning Module** consisted of the same comfort lecture, plus a project-based assignment (the comfort assignment) stemming from the lecture; however, these students were asked to discuss their thoughts and findings from the comfort assignment along with their submissions. Students for this group were assigned to comment on two submissions made by their classmates and they were offered 2 extra credit points to respond individually to a discussion prompt (Fig. 1-3). This intervention added another level of critical thinking beyond the traditional learning module and gave both the original posting students and replying peers an opportunity to reflect and interpret their thoughts. At the end of the experiment students were asked to write down a self-assessment report called ‘self-reflection.’ In this report students were required to reflect upon their learning experience for the class and write their reports on a form obtained from PBLWORKS (See Appendix). Instructions were explained to students through an email sent by the instructor (Fig. 2). For this intervention, the total number of students yielded 40.

Dear Students in Section Demuth:

You are asked to create a post to this discussion board that discusses your progress on the current comfort assignment and is intended to support your submission and your overall understanding of comfort. Write your post sometime **before Monday, 9/21 at 10pm**, although you are welcome to post earlier. If you can, take a few minutes to see what peers in your section are discussing.

In your post, first give an example of one instance of thermal or visual discomfort you observed, stating its source and some basic information about influencing comfort factors. Then answer the following questions in the body of your post:

1. Provide a proposed solution to this comfort issue
2. Describe how the comfort solution would impact energy usage by the building
3. Consider how users are involved in the comfort issue and/or comfort solution. Do the building controls give users the capability to adjust to their environment (thermal and lighting) and/or are users adapting (i.e., with clothing, location in the room, etc.) to attain comfort? What factors (i.e., confusion, inconvenience) are preventing involvement of users in comfort solutions?
4. How would the involvement of users in the comfort issue be different between public buildings and private homes

**Figure 4**. Instruction sent to students in Individual PBL group regarding their discussion prompts.

NOTE: THIS ASSIGNMENT IS FOR STUDENTS IN DEMUTH'S LAB SECTION
This assignment is mandatory. When completed, you will be given 2 extra credit points (same value as a lecture quiz).

**Part 1**: Before **10PM on Monday, 9/28**, use the submission box on this page to re-submit your comfort assignment PDFs. Please note the original requirement that this should be a single PDF and not multiple files. If you submitted separate files, please combine them into one 2-page file.
**Part 2**: Starting on 10PM on Monday, 9/28, you will have 24 hours (until **10PM Tuesday, 9/29**) to complete peer comments on 2 submissions made by your classmates.

**PART 3**: in the upcoming weeks you will be asked to complete and return a form for Project-Based Learning Self Assessment.

Guidance on your comments:
Review the observations and written conclusion. Then add your comments based on these questions:
•Given what you have learned about comfort, do you agree with the assessment of comfort (or discomfort) and the evidence given from the observations?
•Could adjusting controls or other factors in the environment improve comfort. and what might these be?

Be sure to 'save' your comments in Canvas, because if you leave the submission without saving, your comments will be lost.
This whole activity should take you about 10-15 minutes, but it will give you a valuable chance to see what everyone else in your section submitted.

If you have any questions, please let me know.
Michael

Michael D. Gibson, AIA, NCARB, LEED A.P.
Licensed Architect, Kansas and Missouri
Associate Professor
Department of Architecture
Kansas State University
mdgibson@ksu.edu
Office: 1101 Seaton Hall

**Figure 5**. Email sent to Individual PBL group by the professor of the course regarding their class assignment.

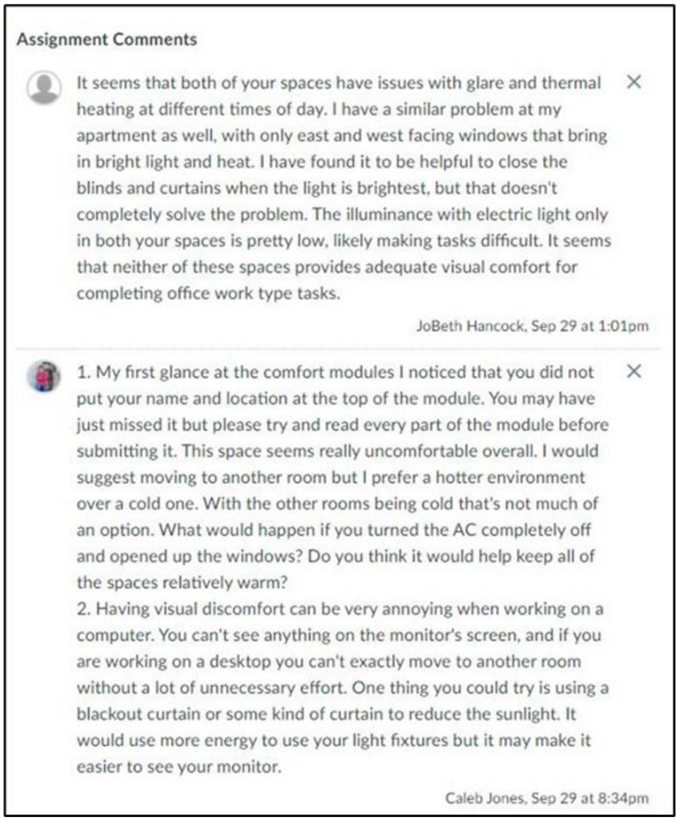


**Figure 6**. Example of students' comments on their classmate's posts in Canvas.

- The **Peer Project-based Learning Module** consisted of the same comfort lecture and assignment from the lecture; plus, students were required to review a poster posted on Canvas and post a brief description on some discussion prompts. It is noteworthy to mention that this information (poster) is the same poster that was used as 'passive information display' in phase one of the study. The purpose that the same poster was used again in this phase, especially for this group, was to explore the importance of participants' involvement in a discussion. Because it was noticed in phase one that just passing off information to building users is not sufficient and does not allow for cultivating meaningful use of controls and comfort. Moreover, it was identified that the poster can contribute to some part of the AMA process and would set participants up to have a better discussion.

The information on the poster provided specific detail about what the controls do, while reminding users that the building systems are using energy, and thus the use of the controls—whether informed or not—will have an impact on the energy use of Seaton Hall. Moreover, students teamed into 8 groups of 5 in which every individual in the group made peer-to-peer presentations on a Zoom call. In the Zoom call, students gave a mini presentation, including 2-3 minutes about their findings and observations from the comfort assignment. They compared their measurements and calculations with the standards (ASHRAE Std. 55) and guidelines (IESNA) given by the professor of the course. After each presentation, students were asked to discuss— up to 10 minutes—their findings and share their thoughts with one another. Instructions were explained to students through an email sent by the instructor (Figs. 4-5). Finally, the 'self-reflection' assignment was given to the students for this group, to increase their level of critical thinking by reflecting on their learning experience while they were doing the class activities. Similarly, this intervention group had 40 students in total.

It is important to clarify that this information (poster) was also given to students in Individual PBL group in an email attachment without explanation of how it linked to their discussion responses. This was done to explore the importance that information alone is not enough, and occupants of the buildings need to undergo a transition that starts with engagement and concludes with a permanent improvement in their behavior and attitude towards energy conservation.


**Figure 7**. The poster that students were required to read and use to answer a couple of discussion prompts.

NOTE THESE DIRECTIVES ARE JUST FOR CRESSWELL'S SECTION.
Dear students in Section Cresswell,

Per the email I sent out yesterday, each lab section is being given a short set of follow-up activities pertaining to the Comfort Assignment you just completed, if you complete all of them, you will receive 2 points (essentially extra credit, equal to a lecture quiz). You are assigned to do the three things below:

**PART 1**: You have a discussion prompt that has been assigned to your group. You should see this come up on your to do list in Canvas, like earlier discussions.

**PART 2**: On Tuesday, 9/29 during our assigned lab time (3:55 to 5:10p) you should join the ESA1 zoom meeting to participate in small group discussions about your submission. The GTAs will divide you into 8 groups with 5 students each, and you should take turns giving a mini presentation (2-3 mins) about your observations and conclusions for the two spaces you used for the assignment. After each presentation, spend a bit of time (up to 10 mins) discussing the assignments.
Here's some guidance on points for discussion:
- Given what you have learned about comfort, do you agree with the assessment of comfort (or discomfort) and the evidence given from the observations?
- Could adjusting controls or other factors in the environment improve comfort, and what might these be?
Participating in the zoom discussion will require you to screen share your submission, so be prepared to do this with your technology. Please keep this small group meetings professional and focused on the ESA1. The GTAs will be checking on the small groups during the session.

**PART 3**: in the upcoming weeks you will be asked to complete and return a form for Peer-Based Learning Self Assessment.

Again, completing all of these things will get you your points.

If you have any questions, please let me know.
Michael

Michael D. Gibson, AIA, NCARB, LEED A.P.
Licensed Architect, Kansas and Missouri
Associate Professor
Department of Architecture
Kansas State University
mdgibson@ksu.edu
Office: 1101 Seaton Hall

**Figure 8**. Email sent to PBL Peer group by the professor of the course regarding their class assignment.

This discussion is Part I of your follow-up assignment for the Comfort Lab. Your response is required (not optional) **before 10p on Tuesday, Sept 29**.

Reviewing your submissions, it reminded me that the student community at APDesign hasn't been instructed on when and how to use the two primary environmental controls in our teaching spaces. The first control is the lighting controls, and the second are the overrides for the HVAC system, which allow you to control temperature.

For this discussion, first review the information presented below (which was compiled for posters in 2018-19 by some research assistants but had not been fully developed). This provides some specific detail about what the controls do, while reminding users that the building systems are using energy and thus the use of the controls (whether informed or not) will have an impact on the energy use of Seaton.

Next, write a brief post of approx. 150 words), doing the following:

1.Reflect on your work in ESA1 and your evaluation of the studio
2.Identify a situation when the controls could/should be used based on your evaluation
3.Explain how the use of the controls would impact energy used by the building systems

Michael D. Gibson, AIA, NCARB, LEED A.P.
Licensed Architect, Kansas and Missouri
Associate Professor
Department of Architecture
Kansas State University
mdgibson@ksu.edu
Office: 1101 Seaton Hall

**Figure 9**. Email sent to PBL Peer group regarding their discussion prompts to the poster.

Including the pre-knowledge survey, the experiment was carried out in eight weeks. In week two, on August 31st, 4 days after the pre-knowledge survey released, all students from the three categories were required to watch the thermal comfort lecture online.

The comfort lecture (thermal) highlighted the following:

I. Knowledge of environmental comfort criteria and the purpose of building systems in maintaining comfort for the occupants.

II. The relationships between comfort and energy usage in buildings, and how comfort problems can cause overuse of active systems, including lighting, heating, and cooling, along with an increase in energy consumed.

III. The impacts of factors such as metabolic activity, acclimatization, age, stress, general health, clothing, and psychological aspects on environmental comfort in various building spaces.

IV. Different parameters of thermal comfort, including dry bulb temperature, humidity, natural ventilation, air velocity and movement, mean radiant temperature, direct radiation, and clothing.

V. Explanations of the recommended thermostatic setpoints for HVAC systems in summertime and wintertime environments, and how these setpoints align with thermal comfort.

VI. Introducing the thermal comfort zone defined by ASHRAE Std. 55, along with the concept of adaptive thermal comfort (where comfort criteria are adapted to local climate conditions).

In week three, on September 3rd, students were asked to watch the visual comfort lecture online (Table 2). The following describes the information covered in comfort lecture (visual):

I. Different parameters of lighting comfort including age, light adaptation, dark adaptation, contrast adaptation, subjective brightness.

II. The benefits of natural light for human health and productivity.

III. The relationships between light and the physiology of the human eye, including the sensitivity of the eye to a remarkable range of luminance.

IV. Explanations of visual comfort conditions as they relate to the type and duration of the task, location in space, and users' preferences and ability to adapt. Concepts such as glare, illuminance, luminance ratio, etc. were also introduced.

V. Introducing the illumination standards defined by IESNA guidelines.

As mentioned earlier, the Traditional Learning Module group only watched the lectures and completed a lab assignment unrelated to the comfort lecture materials without any discussion activity. This group represented a traditional instructional approach where the teacher is a 'sage on the stage' and students mostly listen and write. In contrast, the groups that represent the Project-based Learning modules, in both the individual- and peer-interventions, was given the chance to find answers to their questions by experiencing the problems: through the project-based comfort assignment, discussion board topics, Zoom presentation (for peer group), and the self-reflection report. The main purpose of the comfort assignment (thermal and visual) was to perceive the significance of the materials discussed in the lectures by the teacher, followed by the application of those thoughts and ideas in the real world (Fig. 6-7). The key distinction between these two groups is that the Peer PBL group revealed the role of the peers and their possible influence in learning the materials, while working in a team.

It must be pointed out that the Peer PBL group in this experiment did not do full or 100% PBL group work due to the restrictions caused by COVID-19. It is true that there was a peer interaction component; but under ideal circumstances, students would be working together for the whole project one-on-one. This undoubtedly will reinforce students' engagement in group projects more and let students answer to the real-world problems in more meaningful ways.

**Table 2**. Experiment Timeline, Fall 2020.

| **Weeks** | **Traditional Learning Module (N[2]=39)** | **PBL_Individual (N=40)** | **PBL_Peer Interaction (N=40)** |
|---|---|---|---|
| 08/26/20 (Week one) | Pre-Knowledge Survey | Pre-Knowledge Survey | Pre-Knowledge Survey |
| 08/31/20 (Week Two) | Thermal Comfort Lecture | Thermal Comfort Lecture | Thermal Comfort Lecture |
| 09/03/20 (Week Three) | Visual Comfort Lecture | Visual Comfort Lecture | Visual Comfort Lecture |
| 09/16/20 (Week Four) | …. | Comfort Assignment | Comfort Assignment |
| 09/23/20 (Week Five) | Unrelated Lab Assignment | Assignment Due | Assignment Due + Peer Discussion |
| 09/29/20 (Week Six) | …. | Peer Comments | Peer-to-peer Presentation |
| 10/06/20 (Week Seven) | …. | Self-reflection Project | Self-reflection Project |
| 10/09/20 (Week Eight) | Follow-up Survey | Follow-up Survey | Follow-up Survey |

[2] N: The number of the participants in groups.

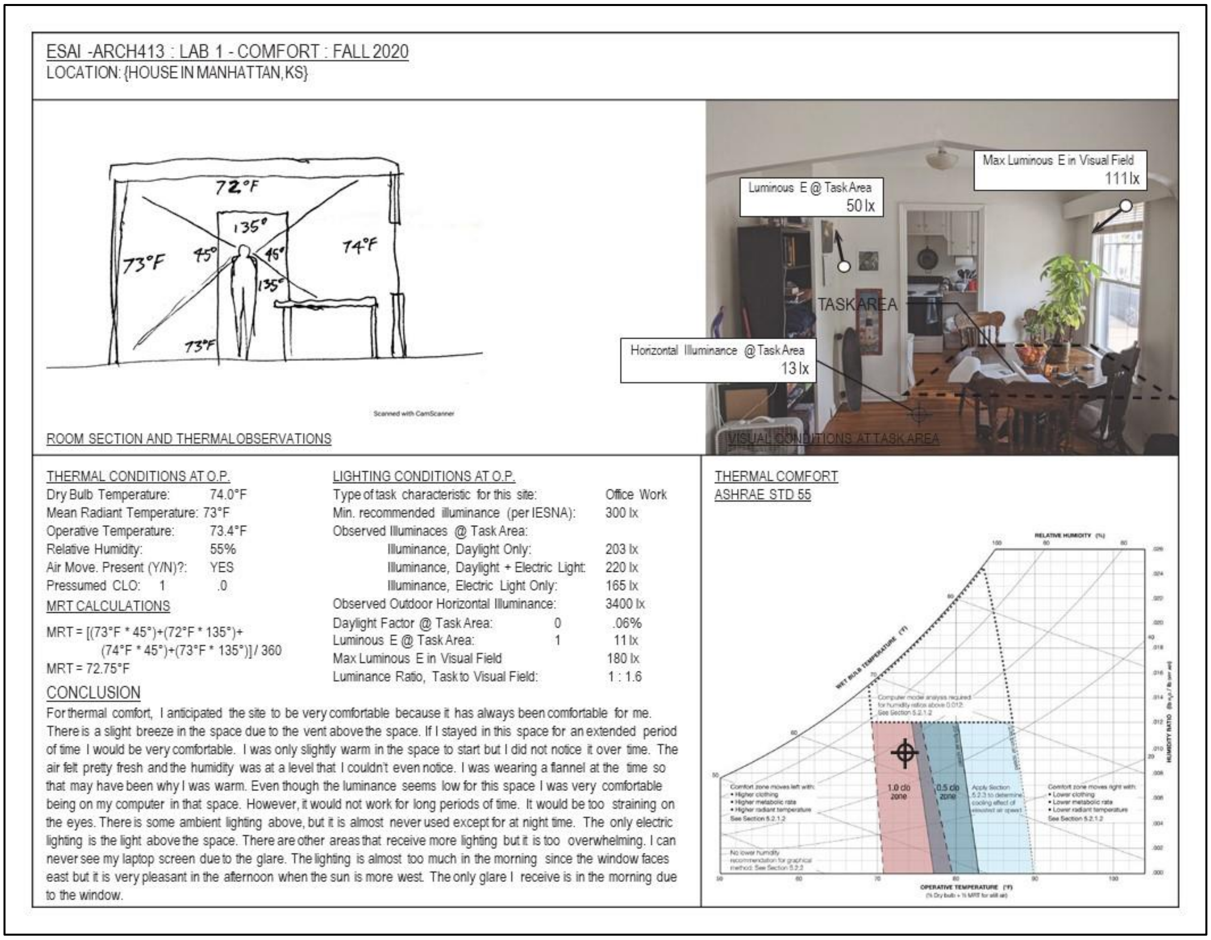


**Figure 10**. Comfort assignment example done by a student (home environment).

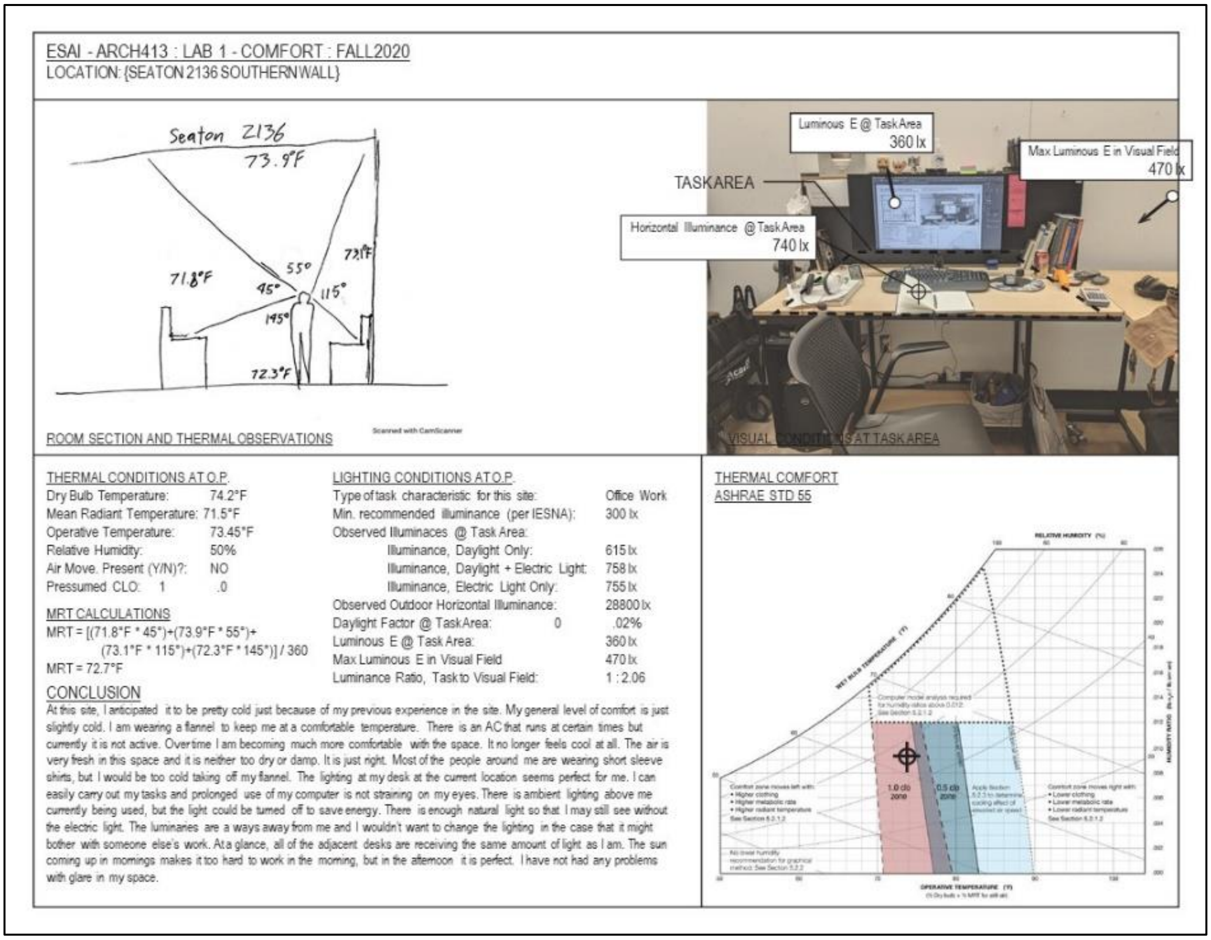


**Figure 11**. Comfort assignment example done by a student (studio environment).

**Follow-up survey**

In the last step towards our goal in this research, a follow-up survey was drafted to measure the effectiveness of the Project-based Learning Module, reflective-learning Module, and the role of peers in the learning effectiveness of participants after the experimental interventions were applied. Three sets of survey questions were drafted for each intervention. In the follow-up survey, students were questioned about the impact of the interventions and class activities on the proper usage time of the building controls either in their home or studio environment. Moreover, some questions in this survey focused on participants' knowledge level of the controls after the interventions, compared with what they reported in the pre-knowledge survey. These questions were designed to capture insights on how, when, and why to use the building controls. Additionally, in all three surveys, students were asked to report that to what degree they believe their classmates were helpful in finding the solutions to their answers in the assignment. This question specifically evaluated the influence of the peers in learning environment. Also, students were asked to what extent they shared their knowledge and understanding of the controls with their friends and family. This question allowed us to obtain some insight about the degree of information diffused amongst students' friends and families after they watched Comfort lecture, did the assignment, had peer-to-peer interaction (Peer PBL group), and discussed the assignment findings on Canvas (Peer PBL and Individual PBL). To gain more specific insight to why students used building controls after the interventions applied in their studio, they were asked to rank their reasons, most vs. least important, from a scale of 1 to 5 (1=most important, 5=least important). The responses were: (a) minimizing the energy costs at my home, (b) conserving energy, (c) minimizing greenhouse gas emissions, (d) increasing or maintaining my comfort. Similarly, students were asked to rank, from a scale 1 to 5 (1=most influence, 5=least important), the individual/s who influenced their use of controls (most/least) in either their home or studio environment. Finally, to measure the value and benefits of self-reflective learning in this study, students in the Peer PBL and Individual PBL groups were required to answer that how much they believed the ‘self-reflection’ report helped them towards their learning path. As discussed earlier in chapter 2, reflecting on experience or observations helps individuals to make connections between what they have experienced and what they have learned. More precisely, reflection helps reinforce the relevance of the project in learning about specific topics and themes. Therefore, by asking about the benefits of ‘self-reflection’ report in the follow-up survey, this research was interested to know how much reflecting on their experience from class activities have been very beneficial to respondents’ comfort and control learning.

# Chapter 4 – Results and discussion

The data analysis for this study consisted of a descriptive analysis and multiple Analysis of Variances (ANOVA) tests using Minitab, a statistic software for analyzing data. This method of analysis was used because there was more than one population group. Starting with the first analysis method, descriptive analyses helped to visualize and broadly view the survey responses' spectrum and identify areas of concern that preceded the experiment. As mentioned earlier, the main purpose of the pre-knowledge survey test was to measure and assess general levels of knowledge, motivation, and actions of the subjects in the study regarding controls and comfort, either at their current residences (i.e., on or off campus housings) or design labs (i.e., studio spaces). Additionally, it was a reasonable approach that helps to understand, to some extent, the energy consumption routine of the participants in their space in the middle of the pandemic based on participants' report. The following selected trends were detected from analyzing the responses.

**Descriptive analysis — general knowledge and awareness levels (Pre-knowledge survey)**

In general, the results of the pre-knowledge survey demonstrated that the target population has a fair amount of awareness about their environmental comfort, either at their current residences or their design labs. For instance, when they were asked whether they can recognize when the environment in their studio is too cold or too warm, around 86% of them have reported "yes" to this question. Similarly, when they were asked the same question, but this time about the freshness and staleness of their studio air environment, 47% reported "yes." As mentioned earlier, findings of the survey indicated that participants' awareness level is also high in terms of environmental conditions at their current residences. For example, 77% of the participants have reported that they are able to recognize when the environment in their dorm, apartment, or house is dry or damp.

Likewise, 78% of the participants answered “yes” when they were asked whether they can recognize when the environment in their dorm, apartment, or house is fresh or stale. Participants were also asked to report how they perceive the current environment in their dorm, apartment, and house, for the assessment of their comfort-awareness level (Fig. 12).

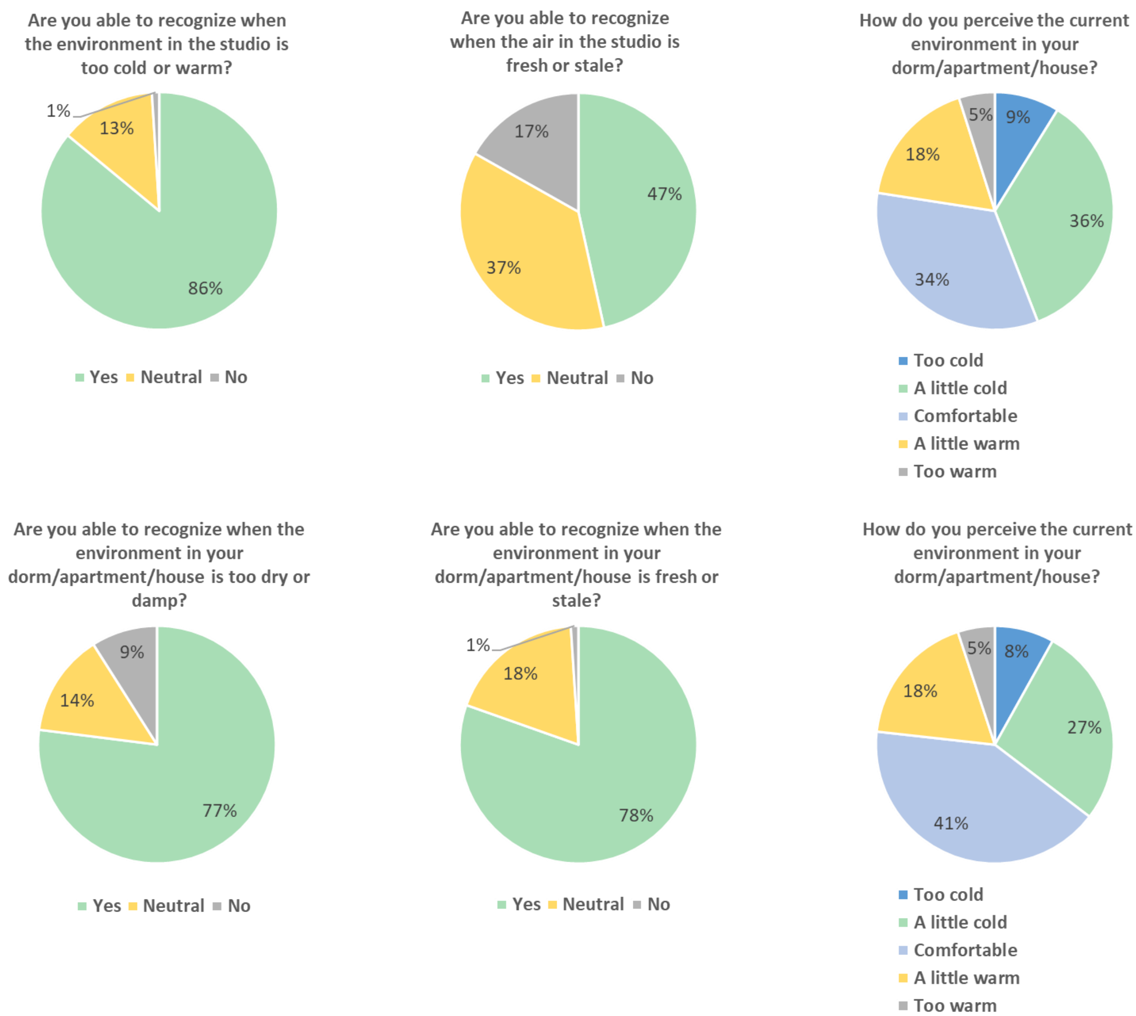


**Figure 12**. Survey responses – participants’ environmental awareness level both at their design lab (top) and home (bottom).

### Awareness or knowledge — controls

Results from the pre-knowledge survey showed that around 60% of the participants answered “no” when asked if they were aware of the location of the VAV controls in the studios. This finding contradicts what was anticipated from the population group of third-year Architecture students, who were believed to have grown a reasonably high knowledge about the location of the building’s smart features. Moreover, results from the pre-knowledge survey revealed that around 57% of the participants answered “no knowledgeable at all” when they were asked about their knowledge of their studio’s VAV controls. Only 4% answered that they were “very knowledgeable” in the VAV operation in the studio. This once again highlights that the population’s general knowledge of the VAV controls’ locations and operation is low, despite their academic level and suggests that students must be informed about the controls (location/operation) in green buildings. Furthermore, as illustrated in Fig.13, when participants were asked if they are knowledgeable in recognizing when the appropriate time is to adjust the VAV controls in their studio, almost 68% of them answered “not knowledgeable at all” again, indicating their studio’s VAV control awareness level is low. In total, it was discovered that the population group in this study has slight or no knowledge of their studio’s VAV controls. They do not know where to locate them, or how and when to operate these overrides in the studios. This finding is similar to what was found in phase one of this study, which once again illustrates lack of awareness or knowledge due to the complexity of the controls in the building to the users.

In contrast to studio’s VAV control knowledge, participants report from the pre-knowledge survey demonstrated that lighting and dimming controls’ knowledge seems to be high. In the pre-knowledge survey, the same questions were asked from the participants about the lighting and dimming controls. When participants were asked if they are aware of the location of the lighting and dimming controls in their studios, almost 90% of them answered “yes.” Additionally, the results showed that around 36% of the participants were “moderately knowledgeable” and 29% were “very knowledgeable” in the operation of the lighting and dimming controls in their studios. Also, results demonstrated that participants, to some degree, are knowledgeable about the appropriate time for manipulating the dimming and lighting controls, with 37% reporting they were “moderately knowledgeable” and 27% reporting they were “very knowledgeable” (Fig. 14). These interesting findings can be attributed to the shapes, styles, or the designs of the dimming and lighting controls. These controls, in general, are much easier to work with due their simplicity in their design and operations (Fig. 15). Smart lighting and dimming controls have usually a slider that is simply designed and straightforward to use. Sliders display either on/off options on light switches or light intensity levels of the dimmers. The VAV overrides, on the other hand, do not have the same screen design feature. These controls usually display a few more information on their screens and have more than one or two keys than the light switches and the dimmers. Therefore, it comes naturally that why respondents in this study or in general green building users have more knowledge towards lighting and dimming controls than VAV overrides. Moreover, since the light intensity varies during the day and does not rely heavily on the seasons, students in the studio use lighting and dimming switches more often than the VAV controls. This circumstance obviously compels users of the building to locate these overrides and use them to respond to their visual comfort needs.

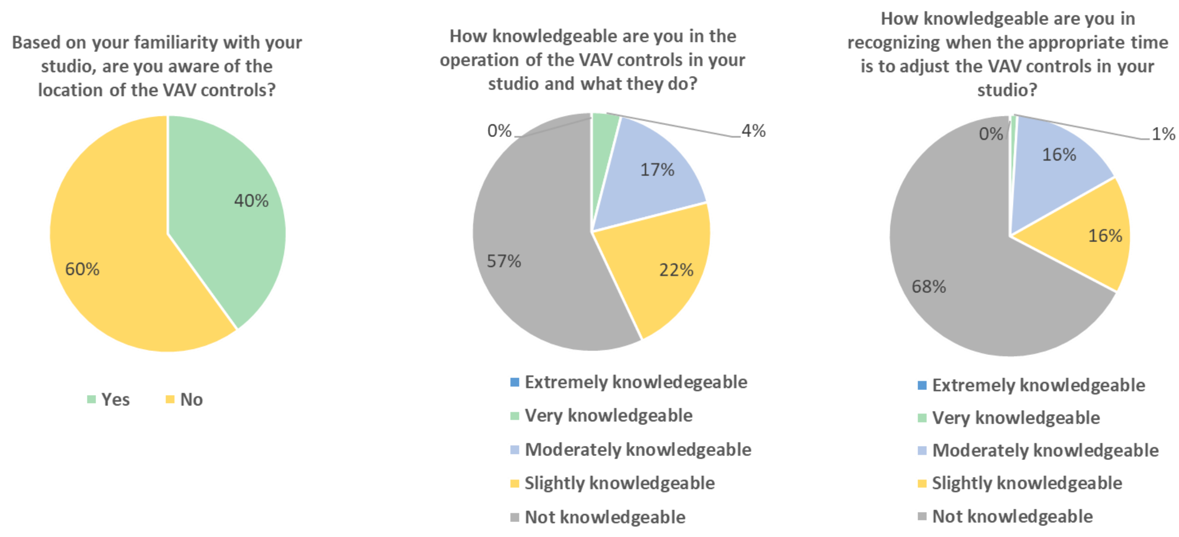


**Figure 13**. Survey responses – participants' VAV control knowledge level (design lab).

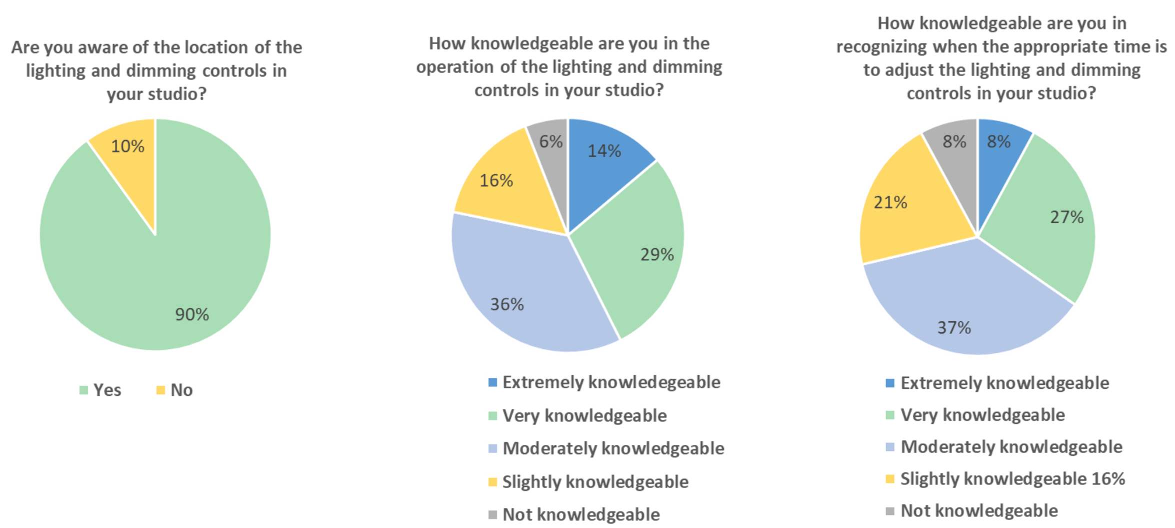


**Figure 14**. Survey responses – participants' lighting and dimming control knowledge level (design lab).


(a) (b) (c)

**Figure 15**. Types of building controls: (a) A smart VAV override, (b) A smart light switch, (c) A smart dimmer (Image sources: grainger.com, enersavesolutions.com, lbclightingpro.com).

### Actions taken towards controls and comfort (design lab or studio)

As mentioned earlier, VAV overrides in the studio environment help to adjust the temperature by +2F and -2F. Particularly, these controls vary the airflow at a constant temperature. Therefore, operation of these overrides is very critical for users to respond to the possible thermal discomfort. However, the pre-knowledge survey results have revealed that VAV control's frequency of usage in the studios is not very high. Around 68% of the participants answered "never" and 21% answered "hardly at all—only if there is a serious issue" when they were asked how often they use the VAV controls in their studio to adjust the temperature. The possible explanation for this finding again may also be attributed to the time when the pre-knowledge survey was conducted. It would have been a time when thermal comfort would be less affected by climate and the temperature in the building. These controls are being used most in the winter. Therefore, it makes sense that students report in the pre-knowledge survey indicates less usage of these controls. Perhaps, if this question was asked in the cold season, results would have been different.

In contrast to the knowledge level of lighting and diming controls, results showed that 41% of the participants reported that they use lighting controls “hardly at all—only if there is a serious issue” and 21% have reported “sometimes—once a week.” Only 3% of them reported “very frequently—every day.” Combining the results, it can be observed that on/off light switches are being used infrequently by 57% of users. It was also seen that dimming controls are used infrequently by users. It worth mentioning that the functionality of the dimming controls differs from the lighting controls. Unlike the light switches that are being used to turn lights on/off, dimmers allow users to adjust the light level (intensity). However, when the results between the usage of lighting and dimming controls were compared, it was realized that dimming controls’ frequency of usage is even less than the lighting controls. Almost 46% of the participants reported “hardly at all—only if there is a serious issue”, 20% have reported “sometimes—once a week” and only 2% have reported “very frequently—every day” (Fig. 16).

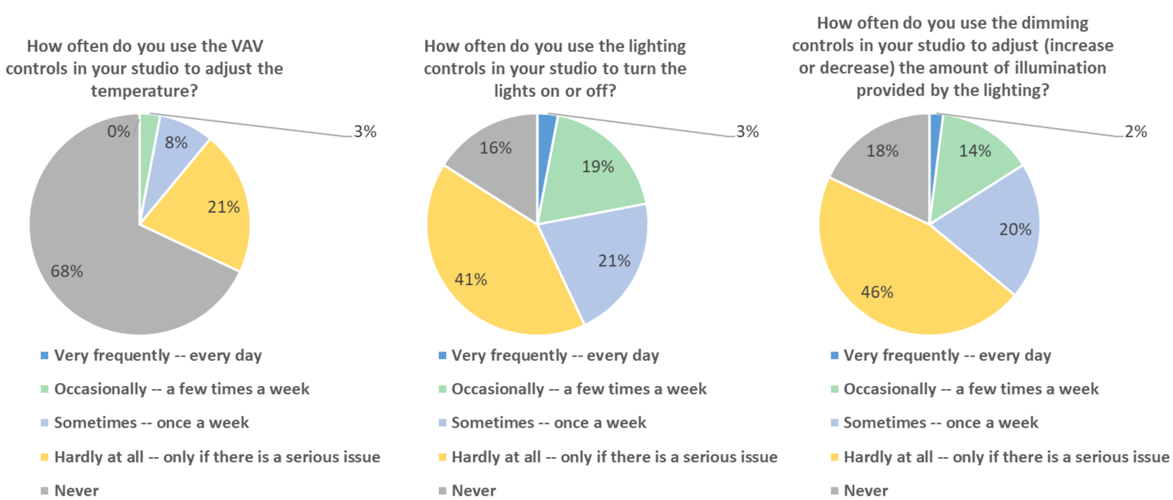


**Figure 16**. Survey responses – participants controls’ frequency of usage (design lab).

This gap between the knowledge level of the participants and their usage level of the lighting and dimming controls can be related to the fact that respondents may not feel the need to ask their classmates to turn the lights off or dim the lights when few individuals are in the studios or while the studio is unoccupied. To some degree, this explanation is consistent with other results from the pre-knowledge survey. Results from the AMA process questions demonstrated that a majority of participants agreed that they do not consider themselves as someone who approaches their classmates to turn the lights on/off or dim them. Particularly, if they realize that no one is in the studio or a few people are left in the studio.

Surprisingly, this was not for the case when respondents were asked about the actions they took if they were the last person leaving the studio. A majority of participants (roughly 45%, if combined) reported that they are the kind of person who would take action and turn off the lights (Fig. 17). This explains that about twenty-five percent of participants will take action once they realize that their actions will not impact on their classmates. Students may feel that their actions taken towards lighting or dimming controls will disturb their classmates' performance, thereby abstaining to ask them to turn the lights off or dim the lights, which results in fewer actions taken towards the lighting and dimming controls.  In other words, it suggests that participants have an awareness of the controls and comfort in their studio, but their motivation, which is avoiding the disturbance of their classmates, does not allow them to take any further actions and turn the lights off or dim them. This can also be related to the relationships shaped between the students in each studio and highlights the role of the peers in the experiment. It was understood that if the bonds or social connections between peers become stronger, there is a high potentiality for increasing the actions taken by the students in the building towards comfort and energy savings.

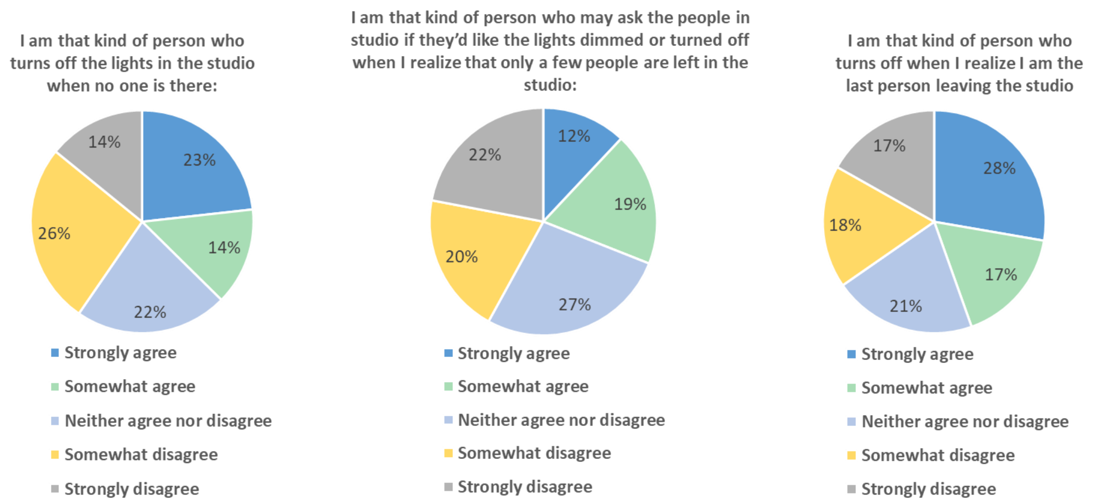


**Figure 17**. Survey responses – participants' AMA process towards lighting and dimming controls (design lab).

Moreover, it was noticed that participants take actions when they feel uncomfortable in their studio as a result of glare created from daylight. In this case, glare is the main motivator for the respondents to take actions towards their comfort. The questions that were designed to capture the students' AMA process associated with the window shades showed that almost 34% of them reported "somewhat agree" and 28% reported "strongly agree" about the usage of shades to deal with glare. Similarly, findings depicted that 33% of the respondents answered, "strongly agree" and 34% answered "somewhat agree" that they take actions towards window shades to address a temporary visual discomfort (like glare). Only 4% reported "strongly disagree" to this question. These discoveries confirm once again that participants in this study have a fair amount of environmental awareness and they will take actions if they notice glare is creating discomfort for them, but not necessarily for creating privacy (Fig. 18).

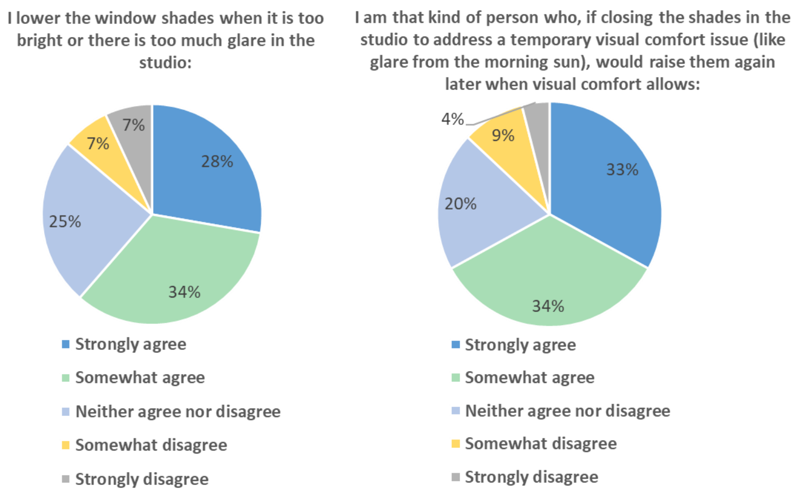


**Figure 18**. Survey responses – AMA process of participants regarding the window shades in studio.

## Home environmental comfort and controls – Awareness, motivation, and actions

The next group of questions covers the level of awareness, motivation, and actions of the participants at their current residences. It was observed that from all the students who had participated in the pre-knowledge survey, only 2 individuals did not come to school at all. The other 99 students were able to answer questions directed at both design lab and home environments. In general, it was seen that the general knowledge or awareness of the participants is the same as what they have reported in the design lab (i.e., their work environment). For instance, reports showed that more than 95% of the participants could identify the current temperature set-point on the thermostat in their homes. Only 1% reported "I do not know how to read the set-point from the thermostat," and 3% said that "I do not control the temperature in my dorm/apartment/house (there is no thermostat in my living space)." This finding opposed what they reported about the VAV controls usage and knowledge in their studios and confirms that the complexity/ignorance and locations of the controls could be a possible reason why the VAV controls have not succeeded as part of an energy conservation plan (Fig. 19).

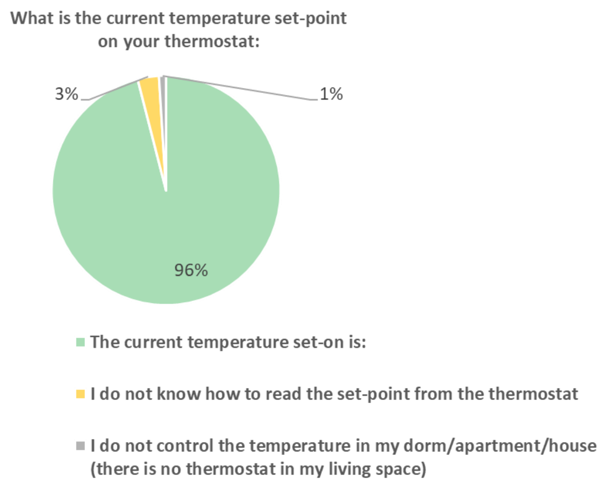


**Figure 19**. Survey responses – participants' awareness about the temperature set-point at their current residences.

Furthermore, an interesting finding was that when participants were asked to identify whether they used environmental controls in Seaton and Regnier Halls in a way that conserves energy, a vast majority of them, around 47%, answered "neither agree nor disagree." The same question was asked regarding their home controls, and more than 50% of the participants answered "somewhat agree" to this question. It is obvious that participants at home have a clearer understanding of the energy saving goals. Utility bills, accessibility of, or simplicity of the controls may motivate them to conserve more energy and exercise more control over the building system. But when it comes to green buildings, it is very likely that building users take fewer actions due to the fact that green buildings, especially commercial, are designed to save energy with or without the occupants' actions (Fig. 20). This finding demonstrates a disconnection between users' actions and the way that controls are intended to supplement automated building systems. These controls in green building are designed to give users (owners/occupants) some decision-making power to become more comfortable in their spaces. However, what observed here was that in Seaton and Regnier Halls, occupants do not treat the building like their home environment. Their actions or decisions towards the controls and comfort are possibly making energy consumption worse. Other scholars such as Elie Azar et al. and Karjalainen found a very similar trend in their research findings. They found out that building occupants take more actions at their home than their work environment because of the level of control they have over the building systems [50, 51]. In overall, it was noticed that participants in this study need to have strong intent or desire to help save more energy at Seaton and Regnier Halls in addition to having access to building control systems and this will be possible if proper education is offered.

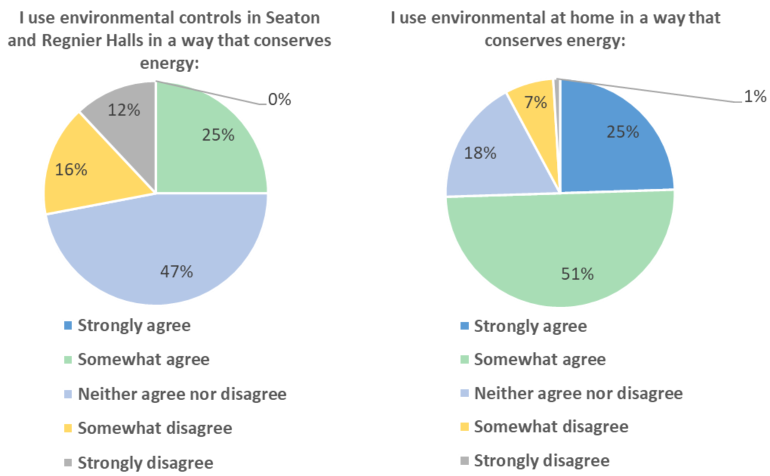


**Figure 20.** Survey responses – building controls usages for energy conservation goals (design lab vs. home).

## General Information

Findings from the last section of the pre-knowledge survey were quite interesting. Participants were asked if there had been enough information provided by the university administration on the appropriate use of environmental controls in Seaton and Regnier Halls; 39%

and 26% reported “somewhat disagree” and “strongly disagree,” respectively, to this question. This suggests that enough information regarding the building controls at green schools or buildings has not properly diffused amongst users so that they can easily locate the controls and know how and when to use them in a way that contributes to resource savings (Fig. 21).

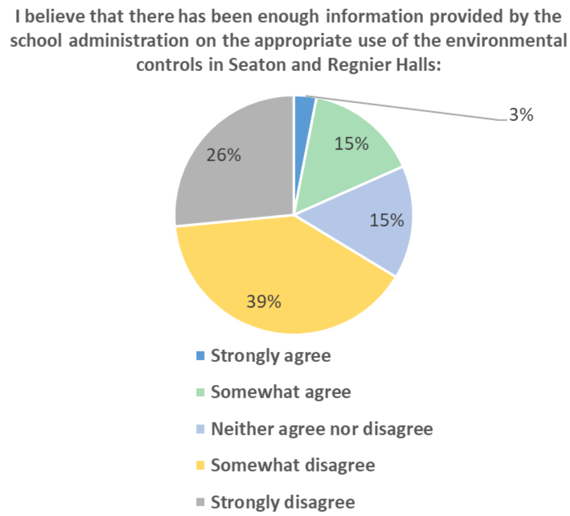


**Figure 21**. Survey responses – information provided by school administration on the appropriate usage of the controls in the buildings.

Finally, the last few questions in the pre-knowledge survey were designed to capture the influence and impact of the teachers, peers, and families of the participants regarding the appropriate usage of the environmental controls either at home or school. Participants’ reports indicated that their classmates and teachers who are in their classes or studios with them have a fair amount of influence on the way that they operate the environmental controls. This finding helped to reveal the capability of peers and classmates’ influence on students to take actions and become more aware of environmental comfort and controls (Figs. 22). Participants also reported that they share their knowledge and understanding of environmental controls with their friends, roommates, and families in their homes, whether at the KSU campus or elsewhere (Figs. 23).

In summary, results from the pre-knowledge survey helped to determine that participants have the capabilities to become knowledgeable and motivated to take actions towards energy savings. However, some hindrances, such as concern for their classmate's disturbance, lack of control over the building's smart features, and not enough information about the usage of the controls prevent them from taking more pro-environmental actions to support energy savings. Having a broad knowledge about above mentioned will evidently help to tackle the issue and reach a better outcome.

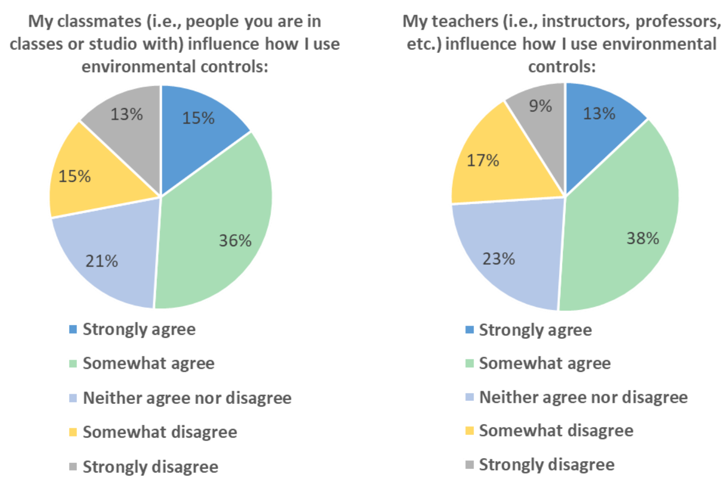


**Figure 22**. Survey responses – classmates and teachers influence on controls' usage level.

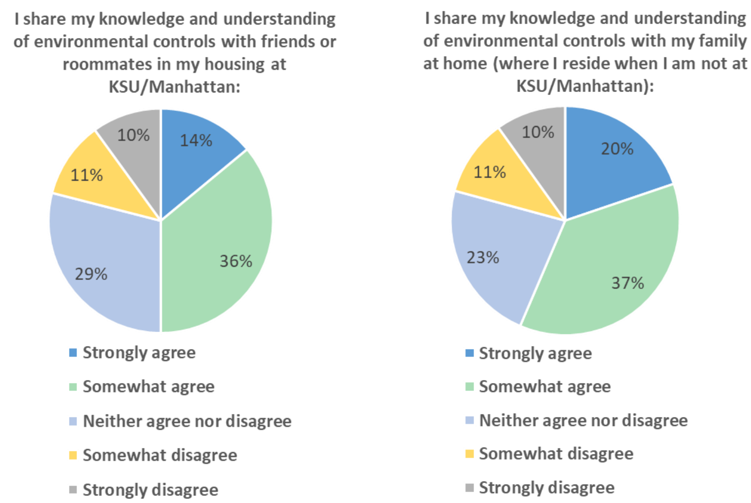


**Figure 23**. Survey responses – level of controls' knowledge sharing with family at home.

## Analysis of variances (ANOVA) — Follow-up surveys

As described at the beginning of this chapter, ANOVA has been used to determine the differences observed in the variances of more than two population groups. In this study, since the follow-up survey was distributed among three population groups (Traditional Learning Module, Individual PBL, Peer PBL), a one-way ANOVA analysis was used to describe differences seen in variances and means of the three groups. Generally, in analysis of the data using ANOVA, two important assumptions must be considered. The first assumption is that for each treatment (group), the values follow a normal distribution; all questions for the three treatments have met this assumption. The second assumption is that all treatments must have the same variance. In statistics, this kind of assumption is called the 'null hypothesis', which is the hypothesis that argues that there are no significant differences between the populations. In the next step, when the validity of the equal variances has been accepted (using Bartlett's test), whether at least one mean in the treatments is different from the other ones must be examined (pos- hoc multiple comparison tests--Tukey Pairwise Comparison test). This method of analysis demonstrates which treatment or group differs from the other groups. While this difference in means has been observed, it can be concluded, based on the researcher hypothesis (alternative hypothesis), whether the experimental interventions have had any impacts on the subjects or not. In this research the significance level of difference was set at 5% ($p<.05$). For the follow-up survey, the collected data related to 'action' of participants is also considered as self-report data.

**Knowledge level of VAV, lighting, and dimming controls after class activities applied**

This section explores whether the interventions or class activities applied in the experiment on the subjects have had any impacts on the VAV, lighting, and dimming controls' knowledge level of the participants. Starting with the VAV overrides (thermostat), results from Bartlett's test in ANOVA for the second assumption (equality in the variances) showed that the p-value = 0.100 is not significant. This shows that the null hypothesis should not be rejected, and treatments have the same variance (Table 3). After equal variances were assumed for the analysis, the variability in the means of all three treatments using Tukey Pairwise Comparisons test was checked. Results from this test showed that the Traditional Learning Module group versus Peer PBL group are significantly different with the p-value = 0.012. However, this was not the case for the Traditional Learning Module group versus Individual PBL group. The p-value for these groups was found to be 0.514, which was not significant. It was also checked whether any differences in the means of the two PBL groups can be observed. According to results from the analysis, the p-value for these two groups was marginally significant and was 0.123. In all, it was concluded that the experimental interventions or the class activities applied in this study have had significant impacts on the Peer PBL group and marginal impacts on the Individual PBL group (Table 4-5).

**Table 3**. Bartlett's test results (ANOVA) —VAV overrides knowledge level after class activities applied.

| Factors | N | StDev[3] | CI[4] |
|---|---|---|---|
| PBL_Individual Group | 37 | 0.688821 | (0.536188, 0.95165) |
| PBL_Peer Group | 27 | 0.919866 | (0.688946, 1.35910) |
| Traditional Learning Module Group | 30 | 0.994236 | (0.754750, 1.43392) |

*Individual confidence level = 98.3333%,*
***α=0.05, p-value=0.100***

**Table 4**. Tukey Pairwise Comparison, 95% Confidence, for VAV knowledge level—Analysis of the means.

| Factors | N | Mean | Grouping | |
|---|---|---|---|---|
| Traditional Learning Group | 30 | 2.667 | A | |
| PBL_Individual Group | 37 | 2.432 | A | B |
| PBL_Peer Group | 27 | 2.000 | | B |

*Means that do not share a letter are significantly different*

**Table 5**. Tukey Simultaneous Tests for Differences of Means, VAV knowledge level after class activities applied.

| Difference of Levels | Difference of Means | SE[5] of Difference | 95% CI | T-Value | Adjusted P-Value |
|---|---|---|---|---|---|
| PBL_Peer - PBL_Individual | -0.432 | 0.218 | (-0.953, 0.088) | -1.98 | 0.123 |
| Traditional - PBL_Individual | 0.234 | 0.212 | (-0.271, 0.739) | 1.10 | 0.514 |
| Traditional - PBL_Peer | 0.667 | 0.229 | (0.121, 1.212) | 2.91 | 0.012 |

*Individual confidence level = 98.07%*

The same data analysis was conducted to explore he impacts of class activities on the knowledge level of the participants in lighting and dimming controls. From the Bartlett test (used for showing the validity of the equal variances), it was noticed that the p-value was not significant and was found to be 0.845. This showed that all treatments do not have the same variances and contradicts the second assumption of the ANOVA analysis (Table 6). A possible explanation of this finding can be that participants had a fair amount of knowledge in the operation of the lighting and dimming controls prior to the experiment, and this finding conforms to what they had reported

[3] StDev: Standard Deviation
[4] CI: Confidence Interval
[5] SE: Standard Error

in the pre-knowledge survey in August 2020. In total, it can be concluded that regardless of the class activities or the experimental interventions in this study, lighting and dimming controls seem to be much easier for the building users to locate and work with than the VAV overrides in the design lab or studio. This discovery is also consistent with what it had been observed from the students' report in the pre-knowledge survey regarding their light switches' and dimmers' knowledge level in the studio.

**Table 6**. Bartlett's test results (ANOVA) —lighting and dimming controls' knowledge level after class activities applied.

| Factors | N | StDev | CI |
|---|---|---|---|
| PBL_Individual Group | 37 | 0.69317 | (0.539571, 0.95765) |
| PBL_Peer Group | 27 | 1.03500 | (0.775177, 1.52921) |
| Traditional Learning Module Group | 30 | 0.88409 | (0.671133, 1.27506) |

*Individual confidence level = 98.3333%,*
*$\alpha$=0.05, **p-value**=0.086*

### Impacts of class activities on the use of thermal/lighting controls and window shades

In the follow-up surveys, participants reported to what extent the class activities impacted their use of thermal controls in their space either at home or studio. Comparing the three population groups' variances using Bartlett test, the p-value was found to be 0.377, which confirms the second assumption in ANOVA (Table 7). However, for comparing the means of the population groups in the next step, the means between Traditional Learning group versus the Peer PBL group were seen to be marginally different, indicating that the class activities have had slight impact on these two groups. No significant difference was observed between the Traditional Learning group and the Individual PBL group (Table 8-9). It was also seen that the adjusted p-value between both PBL groups was 0.101, demonstrating again that the means for these groups are marginally different. The reason that the experiment interventions did not impact the controls' frequency usage by participants may be related to the fact that the experiment was conducted in a fairly mild period (August-October), when thermal comfort at home or studio would be less strained by climate.

**Table 7**. Bartlett's test results (ANOVA) —impacts of class activities on the use of thermal controls either at home or studio.

| Factors | N | StDev | CI |
|---|---|---|---|
| PBL_Individual Group | 37 | 0.644915 | (0.502011, 0.89099) |
| PBL_Peer Group | 27 | 0.620174 | (0.464488, 0.91630) |
| Traditional Learning Module Group | 30 | 0.787839 | (0.598069, 1.13625) |

*Individual confidence level = 98.3333%,*
***α**=0.05, **p-value**=0.377*

**Table 8**. Tukey Pairwise Comparison, 95% Confidence, impacts of class activities on the use of thermal controls — Analysis of the means.

| Factors | N | Mean | Grouping |
|---|---|---|---|
| Traditional Learning Group | 30 | 2.000 | A |
| PBL_Individual Group | 37 | 1.973 | A |
| PBL_Peer Group | 27 | 2.333 | A |

*Means that do not share a letter are significantly different*

**Table 9**. Tukey Simultaneous Tests for Differences of Means, impacts of class activities on the use of thermal controls.

| Difference of Levels | Difference of Means | SE of Difference | 95% CI | T-Value | Adjusted P-Value |
|---|---|---|---|---|---|
| PBL_Peer - PBL_Individual | 0.360 | 0.174 | (-0.054, 0.775) | 2.07 | 0.101 |
| Traditional - PBL_Individual | 0.027 | 0.169 | (-0.375, 0.429) | 0.16 | 0.986 |
| Traditional - PBL_Peer | -0.333 | 0.182 | (-0.768, 0.101) | -1.83 | 0.166 |

*Individual confidence level = 98.07%*

The same data analysis was conducted for the class activities' impact on the use of lighting and dimming controls for all three population groups. The Bartlett test confirms the equality of the variances with the p-value = 0.845 (Table 10). Testing the difference in the means of the population groups, it was identified that the class activities had a great impact on the Peer PBL group when compared with the Traditional Learning group. The p-value obtained from this analysis was 0.033. However, no significant difference was observed between the means of the Traditional Learning group versus the Individual PBL group and Peer PBL group versus Individual PBL group (Table 11-12). This finding suggests that the group discussion and Zoom meeting presentations may have compelled students to be more connected to each other by sharing their thoughts and concerns which ends up with more actions towards light switches and dimmers. Interacting in Zoom allowed students to talk to their classmates and identify issues related to environmental discomfort in their studio environment. While observing the Zoom meeting presentations, students understood that since the studio is a 'shared space' and no strong social interaction has been shaped between them, they do not feel comfortable approaching their classmates and asking them if it was OK to turn the lights off or dim them if needed. Similarity, for the home environment, while observing students' discussion on Zoom, many of them realized that selecting the right LEDs and using light switches more often at home, will help much to decrease the electricity utilization by a great extent.

**Table 10**. Bartlett's test results (ANOVA) — impacts of class activities on the use of lighting and dimming controls either at home or studio.

| Factors | N | StDev | CI |
|---|---|---|---|
| PBL_Individual Group | 37 | 0.686638 | (0.534488, 0.94863) |
| PBL_Peer Group | 27 | 0.724028 | (0.542271, 1.06975) |
| Traditional Learning Module Group | 30 | 0.647719 | (0.491700, 0.93416) |

*Individual confidence level = 98.3333%,*
***α**=0.05, **p-value**=0.845*

**Table 11**. Tukey Pairwise Comparison, 95% Confidence, impacts of class activities on the use of lighting and dimming controls — Analysis of the means.

| Factors | N | Mean | Grouping |
|---|---|---|---|
| Traditional Learning Group | 30 | 1.833 | B |
| PBL_Individual Group | 37 | 1.973 | A B |
| PBL_Peer Group | 27 | 2.296 | A |

*Means that do not share a letter are significantly different*

**Table 12**. Tukey Simultaneous Tests for Differences of Means, impacts of class activities on the use of lighting and dimming controls.

| Difference of Levels | Difference of Means | SE of Difference | 95% CI | T-Value | Adjusted P-Value |
|---|---|---|---|---|---|
| PBL_Peer - PBL_Individual | 0.323 | 0.174 | (-0.090, 0.737) | 1.86 | 0.155 |
| Traditional - PBL_Individual | -0.140 | 0.168 | (-0.541, 0.262) | -0.83 | 0.686 |
| Traditional - PBL_Peer | -0.463 | 0.182 | (-0.896, -0.030) | -2.55 | 0.033 |

*Individual confidence level = 98.07%*

Similarly, data analysis revealed the same results for the impacts of class activities on window shades amongst the three population groups. As Table 13 shows, the p-value from the Bartlett test confirms the equality of the variances (second ANOVA assumption) between the groups. Additionally, the analysis of the means reveals that the Traditional Learning group and the Peer PBL group are slightly different with the p-value= 0.058, signifying the class activities have had impacts on the Peer PBL group. Additionally, from the comparison of the means, it was observed that among the two PBL groups, the class activities on the Peer PBL had more impacts on participants’ window shades’ usage level than the Individual PBL group. The obtained p-value for this analysis was 0.033 indicating the impacts of class activities on Peer PBL group regarding window shade utilizations (Table 14-15). This discovery can be substantially correlated once again to the influence and the role of the peers in this group. The social interactions among peers, the groups’ presentation over Zoom, and Canvas group discussion (for both groups) all together show positive role peers can play in helping to translate class activities into learning and actions.

**Table 13**. Bartlett’s test results (ANOVA) — impacts of class activities window shades usage either at home or studio.

| Factors | N | StDev | CI |
|---|---|---|---|
| PBL_Individual Group | 37 | 0.700707 | (0.545441, 0.96807) |
| PBL_Peer Group | 27 | 0.868899 | (0.650774, 1.28379) |
| Traditional Learning Module Group | 30 | 0.698932 | (0.530577, 1.00802) |

*Individual confidence level = 98.3333%,*
***α**=0.05, **p-value**=0.405*

**Table 14**. Tukey Pairwise Comparison, 95% Confidence, impacts of class activities on the use of window shades — Analysis of the means.

| Factors | N | Mean | Grouping | |
|---|---|---|---|---|
| Traditional Learning Group | 30 | 1.833 | A | B |
| PBL_Individual Group | 37 | 1.811 | | B |
| PBL_Peer Group | 27 | 2.296 | A | |

*Means that do not share a letter are significantly different*

**Table 15**. Tukey Simultaneous Tests for Differences of Means, impacts of class activities on the use of window shades.

| Difference of Levels | Difference of Means | SE of Difference | 95% CI | T-Value | Adjusted P-Value |
|---|---|---|---|---|---|
| PBL_Peer - PBL_Individual | 0.485 | 0.190 | (0.032, 0.939) | 2.55 | 0.033 |
| Traditional - PBL_Individual | 0.023 | 0.185 | (-0.418, 0.463) | 0.12 | 0.992 |
| Traditional - PBL_Peer | -0.463 | 0.200 | (-0.938, 0.012) | -2.32 | 0.058 |

*Individual confidence level = 98.07%*

## Classmates/ peer influence

In the three follow-up survey sets, participants were asked to report to what extent their classmates were helpful in reinforcing or informing new knowledge during the comfort assignment. This study sought to find out whether a significant or marginal difference could be observed between the three population groups. In this study, it was anticipated that the group that receives the peer interaction will do better in terms of informing new knowledge or sharing new ideas with one another. Results from the Bartlett test confirms that all three groups have the same variance (Table 16). While the test for analyzing the means of the three population groups was performed, it was detected that the difference between the Traditional Learning group and Peer PBL group is significant with the p-value = 0.023. Interestingly, it was found that the Individual PBL group and the Peer PBL group are also moderately different with the p-value = 0.056 (Table

17-18). This finding supports the initial hypothesis and underscores the influential role of peers in the learning environment that can cultivate meaningful use of controls.

**Table 16**. Bartlett's test results (ANOVA) — classmates or peer influence on informing new knowledge regarding the comfort assignment.

| Factors | N | StDev | CI |
|---|---|---|---|
| PBL_Individual Group | 37 | 1.07105 | (0.833720, 1.47972) |
| PBL_Peer Group | 27 | 1.24493 | (0.932409, 1.83938) |
| Traditional Learning Module Group | 30 | 0.93218 | (0.707644, 1.34443) |

*Individual confidence level = 98.3333%,*
***α**=0.05, **p-value**=0.322*

**Table 17**. Tukey Pairwise Comparison, 95% Confidence, peer influence on the comfort assignment —Analysis of the means.

| Factors | N | Mean | Grouping |
|---|---|---|---|
| Traditional Learning Group | 30 | 3.400 | A |
| PBL_Individual Group | 37 | 3.270 | A B |
| PBL_Peer Group | 27 | 2.630 | A B |

*Means that do not share a letter are significantly different*

**Table 18**. Tukey Simultaneous Tests for Differences of Means, peer influence on the comfort assignment.

| Difference of Levels | Difference of Means | SE of Difference | 95% CI | T-Value | Adjusted P-Value |
|---|---|---|---|---|---|
| PBL_Peer - PBL_Individual | -0.641 | 0.274 | (-1.294, 0.013) | -2.34 | 0.056 |
| Traditional - PBL_Individual | 0.130 | 0.266 | (-0.504, 0.764) | 0.49 | 0.877 |
| Traditional - PBL_Peer | 0.770 | 0.287 | (0.086, 1.455) | 2.68 | 0.023 |

*Individual confidence level = 98.07%*

## Sharing knowledge and advising parents about usage of controls at home

Participants in the follow-up survey were asked to report how likely they will share their understanding and knowledge of controls with their family and friends, based on what they learned from class activities. After the Bartlett test confirmed the equality of the variances (Table 19), the Tukey's test showed that the Traditional Learning group and the Peer PBL group are slightly different, with an adjusted p-value of 0.077. Also, when the means of both PBL groups were analyzed, the adjusted p-value was calculated to be 0.027, indicating that these two groups are significantly different (Table 20-21). This finding suggests that Zoom meeting presentations (about class assignment) by the Peer PBL group has been eye-opening for students to the point that they saw it very essential to share their understanding with their parents. It was witnessed from the Zoom meeting during which students discussed their thermal and visual calculations with their teammates. Many of them noticed that their thermal and visual comfort vary with the standards given by the teacher. They also realized that their thermal and visual calculations even differ from their peers' spaces. This can be a concrete evidence that why students encouraged their parents about the appropriate way of operating controls and what steps need to be taken to improve their comfort at their home. It is also important to mention that students from Peer PBL group learned (from comfort lecture) that for each increase in thermostatics setpoint, the energy consumption level will be increased substantially. This suggests that participants from Peer PBL group saw this concern very essential and realized that sharing this knowledge with their parents is a must.

**Table 19**. Bartlett's test results (ANOVA) — Sharing knowledge with family and friends.

| Factors | N | StDev | CI |
|---|---|---|---|
| PBL_Individual Group | 37 | 0.925125 | (0.720130, 1.27811) |
| PBL_Peer Group | 27 | 0.838870 | (0.628284, 1.23943) |
| Traditional Learning Module Group | 30 | 0.985527 | (0.748139, 1.42136) |

*Individual confidence level = 98.3333%,*
***α**=0.05, **p-value**=0.706*

**Table 20**. Tukey Pairwise Comparison, 95% Confidence, Sharing knowledge with friends and family — Analysis of the means.

| Factors | N | Mean | Grouping | |
|---|---|---|---|---|
| Traditional Learning Group | 30 | 2.167 | A | B |
| PBL_Individual Group | 37 | 2.243 | A | |
| PBL_Peer Group | 27 | 1.630 | | B |

*Means that do not share a letter are significantly different*

**Table 21**. Tukey Simultaneous Tests for Differences of Means, sharing knowledge with friends and family.

| Difference of Levels | Difference of Means | SE of Difference | 95% CI | T-Value | Adjusted P-Value |
|---|---|---|---|---|---|
| PBL_Peer - PBL_Individual | -0.614 | 0.233 | (-1.169, -0.058) | -2.63 | 0.027 |
| Traditional - PBL_Individual | -0.077 | 0.226 | (-0.616, 0.463) | -0.34 | 0.939 |
| Traditional - PBL_Peer | 0.537 | 0.244 | (-0.045, 1.120) | 2.20 | 0.077 |

*Individual confidence level = 98.07%*

Participants were also asked to report how likely they will advise their parents about usage of controls at home, based on what they had learned in class. Very similar to sharing knowledge with parents, in this question the experimental interventions had a noticeable effect on the Peer PBL group (Table 22-24). This finding approves the statement made from the previous analysis.

**Table 22**. Bartlett's test results (ANOVA) — advising parents about home controls usage.

| Factors | N | StDev | CI |
|---|---|---|---|
| PBL_Individual Group | 37 | 1.01490 | (0.790015, 1.40215) |
| PBL_Peer Group | 27 | 1.06752 | (0.799534, 1.57726) |
| Traditional Learning Module Group | 30 | 1.14269 | (0.867448, 1.64803) |

*Individual confidence level = 98.3333%,*
*$\boldsymbol{\alpha}$=0.05, **p-value**=0.799*

**Table 23**. Tukey Pairwise Comparison, 95% Confidence, advising parents about home controls usage — Analysis of the means.

| Factors | N | Mean | Grouping | |
|---|---|---|---|---|
| Traditional Learning Group | 30 | 2.267 | A | B |
| PBL_Individual Group | 37 | 2.243 | A | |
| PBL_Peer Group | 27 | 1.704 | | B |

*Means that do not share a letter are significantly different*

**Table 24**. Tukey Simultaneous Tests for Differences of Means, advising parents about home controls usage.

| Difference of Levels | Difference of Means | SE of Difference | 95% CI | T-Value | Adjusted P-Value |
|---|---|---|---|---|---|
| PBL_Peer - PBL_Individual | -0.729 | 0.271 | (-1.375, -0.082) | -2.69 | 0.023 |
| Traditional - PBL_Individual | -0.166 | 0.263 | (-0.793, 0.462) | -0.63 | 0.804 |
| Traditional - PBL_Peer | 0.563 | 0.284 | (-0.115, 1.241) | 1.98 | 0.123 |

*Individual confidence level = 98.07%*

To understand how much class activities affected motivations to use controls, participants were asked to rank their reasons for using building controls, using a scale of 1 (most important) to 4 (least important), and according to four rationales. The rationales were: (a) minimizing the energy costs at my home, (b) conserving energy, (c) minimizing greenhouse gas emissions, and (d) ensuring, improving, or maintaining my personal comfort. Results from the Traditional Learning group showed that a vast majority of the participants, roughly 63%, ranked ‘minimizing the energy costs at my home’ as their most important reason and ‘minimizing greenhouse gas emissions’ as their least important reason for operating the building controls. For the Individual PBL group, unfortunately, no clear pattern was found from their answers. However, for the Peer PBL group, participants ranked ‘conserving energy’ as their most important reason and ‘ensuring, improving, or maintain my personal comfort’ as their least important reason for controls’ usage. This discovery from the Peer PBL group validates the influence of peer interaction since discussions made between students in this group (in Zoom meeting and Canvas) focused most on the importance of energy conservation and its effects on the environment if controls are not being used properly. Students from this group also gained knowledge that for each increase in the thermostat set point will leave the buildings with more $CO_2$ emissions. Additionally, students introduced to different methods of adaptation to environmental discomfort such as wearing more layers when it is too cold or use table lamps if they are experiencing discomfort (thermal/visual) in their space. These activities mostly revolve around energy efficiency and signify the importance of proper use of controls and encourage other energy-efficient actions to help reach better energy consumption goals (Fig. 24-26).

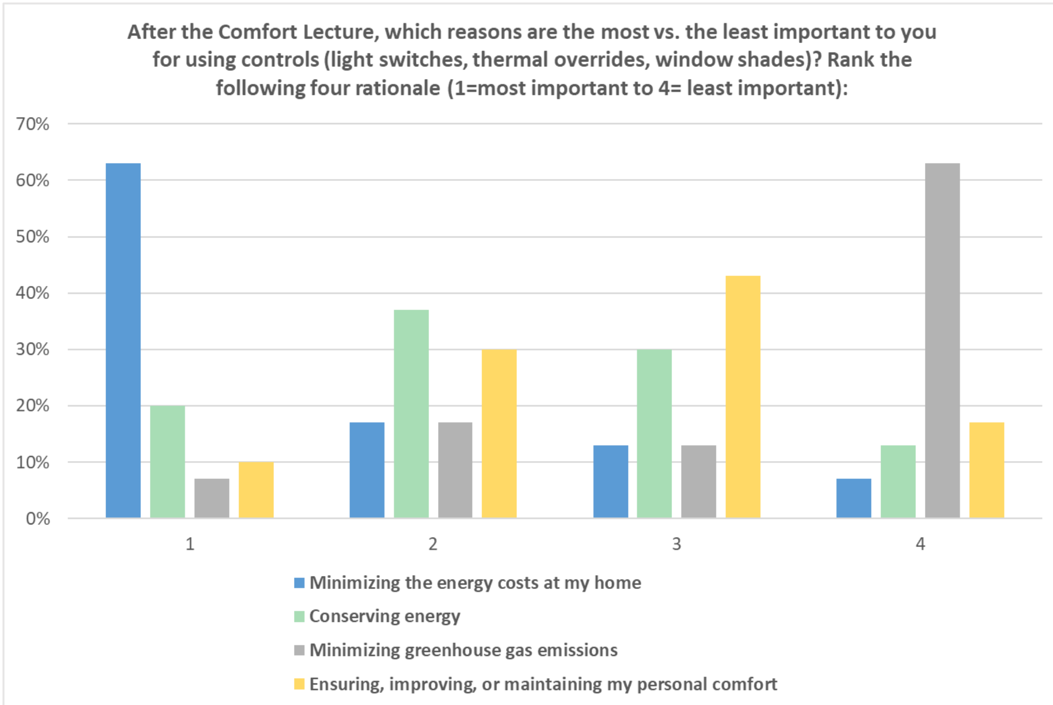


**Figure 24**. Follow-up survey responses, reasons for using the controls (Traditional Learning Module group).

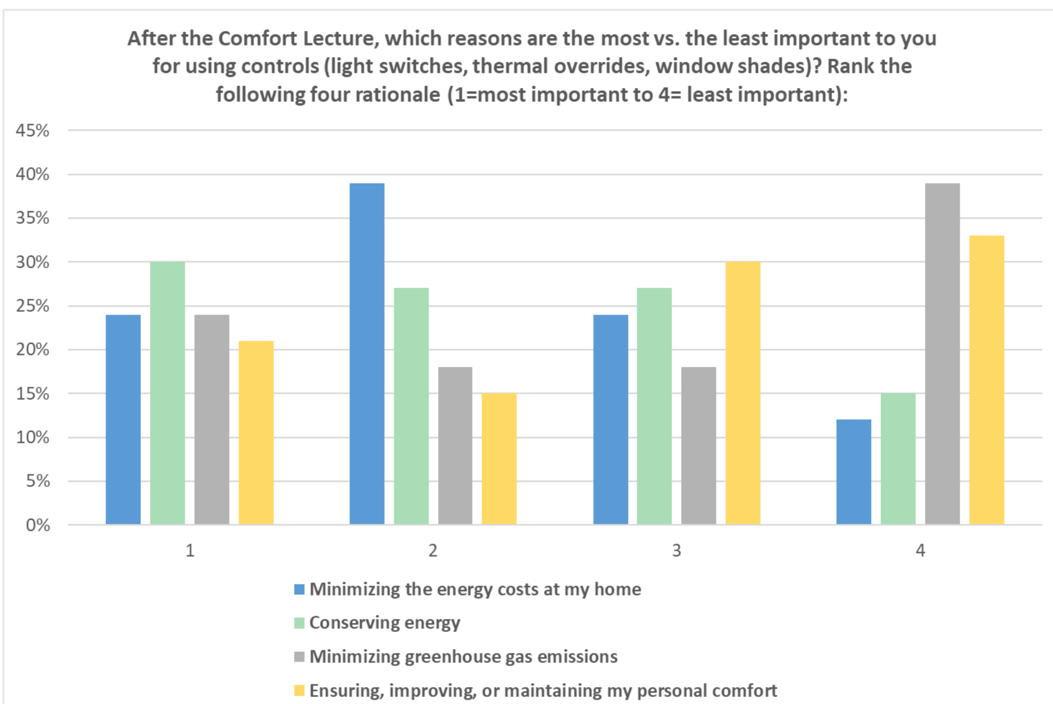


**Figure 25**. Follow-up survey responses, reasons for using the controls (Individual PBL group)

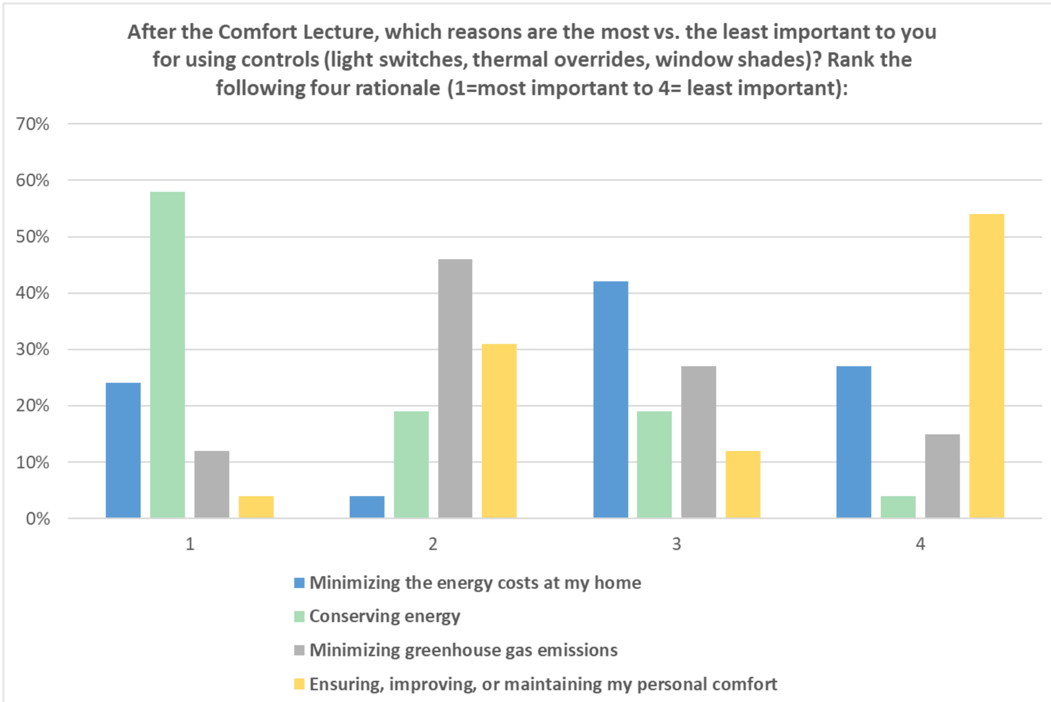


**Figure 26**. Follow-up survey responses, reasons for using the controls (Peer PBL group).

Participants in the follow-up survey were asked to report, from a scale of 1 (most influence) to 5 (little or no influence), who or what influenced them to use the building controls. The options were: (a) your studio teacher, (b) the class activities (lectures, assignments, discussion) you have completed in ESA, (c) a studio classmate who is not part of your social group (i.e., people I spend time with outside of studio), (d) a studio classmate from a different studio, (e) me: if I chose to increase my use of controls, I did it for my own reasons. From the results, it was noticed that the Traditional Learning group has some consensus for the 'me' factor, where nearly 55% of the participants from this group have ranked it as their most influencer. Likewise, results showed that for the Individual PBL group, the 'me' factor was their most important influencer. For the Peer PBL group, surprisingly, it was found that other than class activities and studio teacher, they have also ranked 'me' as their greatest influencer. Additionally, it was observed that their studio classmates are the least influential for the use of building controls. This finding was, to some extent, the opposite of what it was expected despite their active involvement in the class activities. However, it may be related that participants in this groups were being flooded by peer interaction, shifting influence away from individual classmates to put focus on class activities (Fig. 27-29).

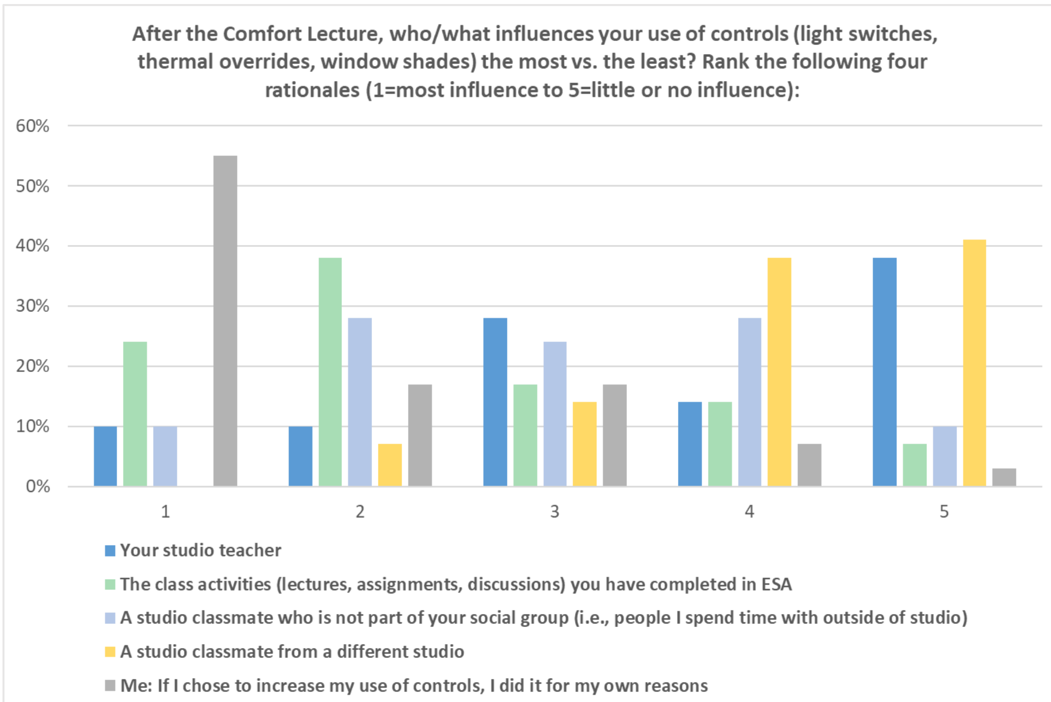


**Figure 27**. Follow-up survey responses, influence on the use of building controls (Traditional Learning Module group).

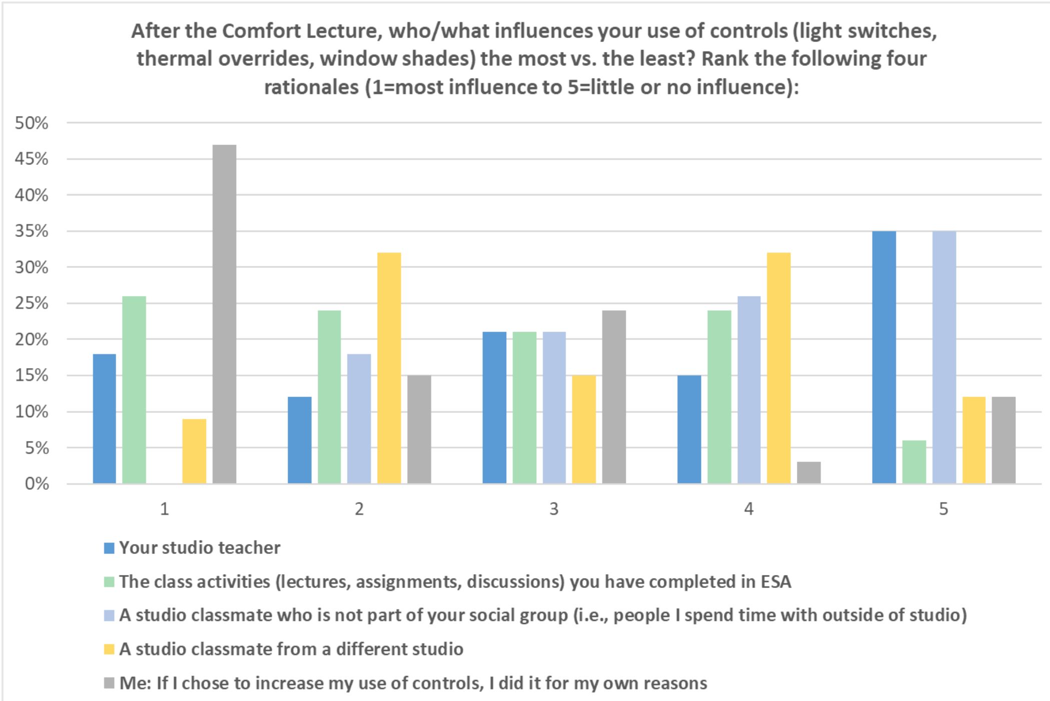


**Figure 28**. Follow-up survey responses, influence on the use of building controls (Individual PBL group)

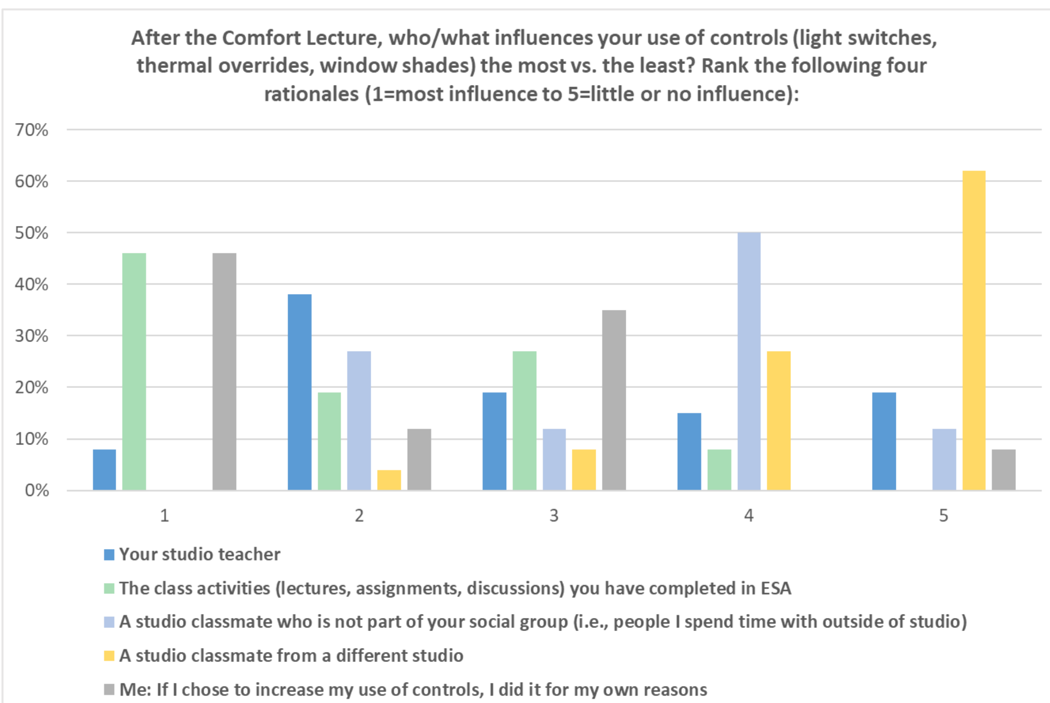


**Figure 29**. Follow-up survey responses, influence on the use of building controls (Peer PBL group)

### Self-reflection — students' report

Respondents in the two PBL groups were asked to report how beneficial and effective they felt the self-reflection report was in their learning path towards environmental comfort and controls in their home and studio. Around 38% reported "moderately" and 27% "very" from the Individual PBL group (Fig. 30). Interestingly, reports from the Peer PBL group indicated that participants felt that the self-reflection report was more beneficial to this group. More than 50% stated that the self-reflection report was 'very' effective regarding their learning (Fig. 31). This discovery was also confirmed from a Two-Sample T-test (two-sided hypothesis test) conducted in Minitab. Using the T-test helped to understand whether there would be any significant difference in the means of these two treatments (groups). The adjusted p-value from T-test was calculated to be 0.001 in which underlines a significant difference in the means of these groups (Table 25).

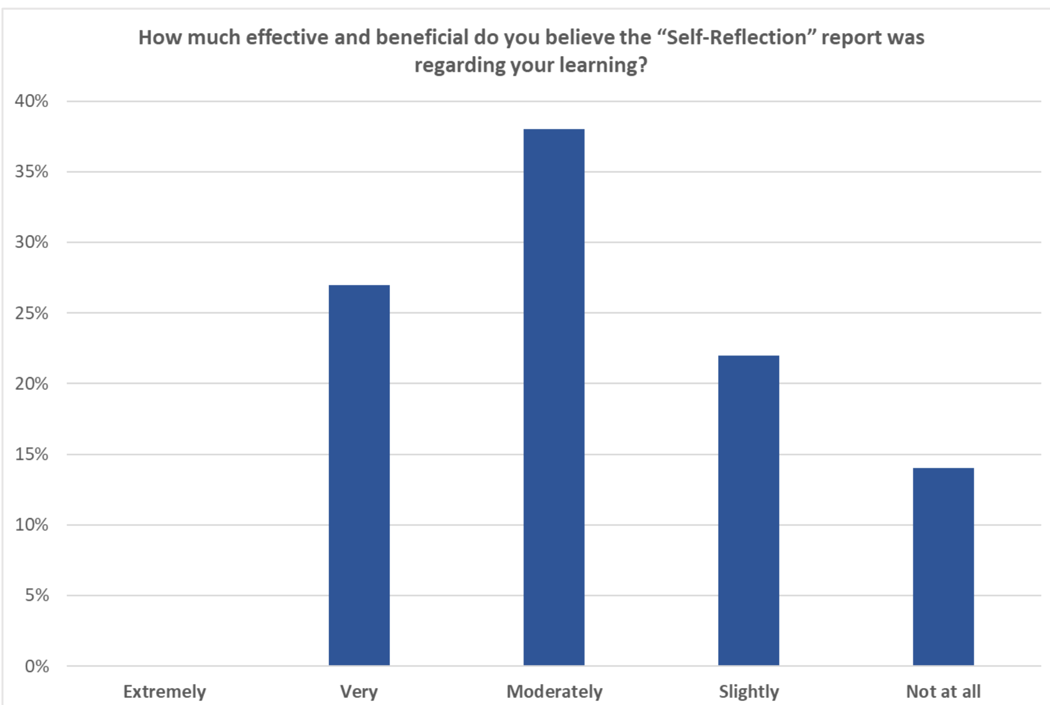


**Figure 30**. Students' report regarding the effectiveness of the self-reflection report (PBL_Individual group).

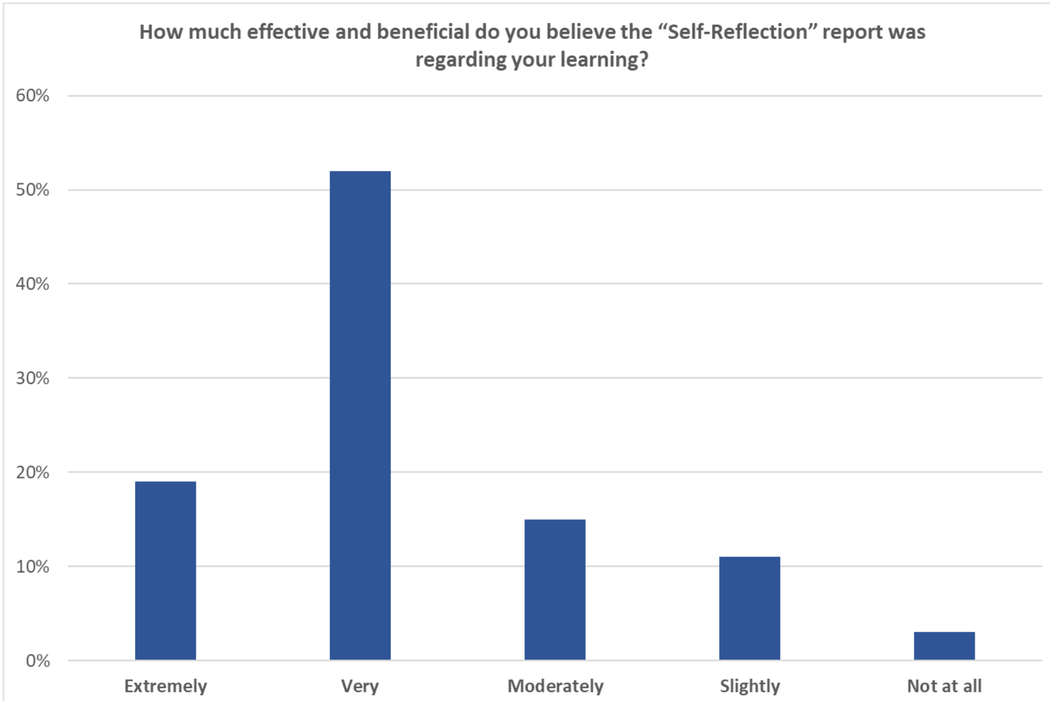


**Figure 31**. Students' report regarding the effectiveness of the self-reflection report (PBL_Peer group).

**Table 25**. Estimation for difference in the means of the treatments (T-test).

| Difference | Pooled StDev | 95% CI for Difference | T-Value | DF | P-Value |
|---|---|---|---|---|---|
| 0.0920 | 1.015 | (0.406, 1.434) | 3.58 | 62 | 0.001 |

A plausible justification to such discoveries from the Peer PBL group compared to Individual PBL group is that the self-reflection report enabled students, especially the Peer PBL group, to critically think about what they had done or experienced during the two months. For instance, when students were asked to outline, in the self-reflection report, what the most enjoyable part of this project was, one student from the Peer PBL group described: "For me, I really enjoyed finding, and compiling the evidence of thermal and visual comfort within my spaces. It is something that I experience but have never been able to see in scientific terms. I really enjoyed feeling like I was actually putting meaning into the measurements of lighting and humidity. Temperature is something you see and can easily measure every day, but to actually see the levels of lighting and humidity was something cool to experience" [Student's report].

Additionally, in the self-reflection report, students were required to identify what is the most important thing you learned in this project. Among all the positive answers received from the students, one individual from the Peer PBL group reiterated: "The most important thing that I learned was how to tell if a room is comfortable. How to measure operative temperature and daylight factors. Then knowing how to graphically organize the data in a chart or diagram that I can understand" [Student's report].

More importantly, many students from both PBL groups shared that the class activities led them to better grasp the building control systems' features, especially at school. Another student from the Peer PBL group reported that "Thermal comfort is something that is super important to the livable condition, and that passive systems are very viable to create a completely passive house if done correctly. The mechanical systems however should not be the primary system and should assist when needed to create a comfortable environment for the users within" [Student's report].

# Chapter 5 – Summary and concluding remarks

## Summary

Evidence showed that giving information to building users alone is not sufficient and does not help much to increase knowledge level and reach the resource conservation goals. It was remarked that in green buildings, technology alone does not guarantee high performance, and creates confusion. Knowledge about environmental controls and comfort in green buildings reinforces sustainable design goals, ensures energy is saved while the occupants better appreciate the quality of space. It is important to mention that the influence of decisions that green building occupants make about operation of such controls is quite often ignored by them and eventually leads to less environmental comfort and excessive usage of energy. Using controls is ideally about making informed decisions that eventually become habitual. This suggests that the behavior of building occupants needs to be improved or possibly changed. Changing behavior obviously is a complicated process and involves learning, motivations, and influence of peers.

Indeed, an educational method that revolves around learning while experiencing is believed to affect building users' learning attitudes and actions towards energy saving targets. This study aimed to evaluate the effectiveness of various educational methods on green building users' knowledge level about environmental comfort and controls. The AMA (awareness, motivation, action) plan explained in this research describes a process where building users can develop informed-habitual decisions which largely facilitate energy saving goals. Such a learning method works best and encourages users to move best through the AMA process.

Educational environments (classrooms, design labs) and residential (dormitory, house, apartment) environments were the focal point of the research. These are the environments that individuals spend most of their time in doing different activities, thereby having a thorough understanding of comfort and controls is vital.

In this research, Project-based Learning (PBL) method was utilized to study how and to what extent active learning contributes to raising awareness, motivation, and finally, action towards energy conservation and better environmental comfort among the green building users. To this end, the newly constructed green buildings, Seaton Hall and Regnier Hall, were chosen as the study site. The study consisted of a series of class activities on three chosen groups, namely, Traditional Learning, Individual PBL, and Peer PBL groups, with the aim of quantifying the effect of PBL and peer influence.

The effectiveness of PBL was verified by the findings of the presented research. For example, class activities were seen to have significant impact on students' report of their use of the window shades both at their design studio and current residences. It is worth mentioning that before applying PBL approach in this study, students report showed that they do not use the shades frequently in their studio. After applying PBL method however, their attitudes towards window shades changed significantly. This learning module raised students' awareness regarding the benefit of natural light for human health and performance, introduced them to the possible side effects of glare created by daylight and resulted in more window shade usage. Moreover, similar observations were made with regards to the impact of PBL module on students' reports on sharing knowledge with family, friends and advising them about the usage of controls. This certainly underlines the significance of PBL module in diffusing information and applying knowledge to real-world problems.

The influence and role of peers in disseminating information was also confirmed by the observations from the study. The results from the study on Peer PBL group showed that working collaboratively with classmates enabled the students to report use of lighting and dimming controls more extensively than before. The Zoom meeting and group discussion compelled students to listen to their classmates' thoughts and find the issue specifically related to the lighting and dimming controls' level of usage (shared space) and share it with one another. Furthermore, many students in their posts on the discussion prompts (Zoom meeting and Canvas) mentioned that the one main reason that lighting and dimming controls are not being used much, despite students' knowledge about them, is that studio is a shared space. Having the group discussion with their studio classmates broke the ice between students in the group to the point that they were able to identify the issues related to the controls' usage and comfort in their studio. This with no doubt helps the students in the studio to come forward and ask their classmates to dim the lights or turn some lights off if needed. In terms of VAV controls operating knowledge, Peer PBL group showed that sharing knowledge about these controls and talking about them with their classmates in the discussion prompts (poster) led them to knowing and identifying these controls better. Even though students' actions towards these controls did not change because of the season in which the knowing about the controls ensures reaching better energy consumption goals.

Lastly, this study confirmed that reflection has a vital role in increasing and expanding students' knowledge towards environmental controls and comfort. As seen in the results, the 'self-reflection report' impelled students, especially from Peer PBL group, to criticize their learning path by reflecting on it. It, in fact, helped students to reflect on their learning experience from the class activities, identify the most/least enjoyable parts, and relate them to their level of understanding.

This research is ultimately hoped to build upon the development of a universal 'Environmental Comfort and Control' toolkit for widescale distribution. This toolkit can be an extension of the original educational tools developed in both phases. The information in this toolkit can also be shared via national channels (such as the USGBC Learning Lab and Center for Green Schools). Such information includes, but is not limited to, the description of specific resources, tools, and activities that can be used by the teachers to integrate concepts/knowledge of the project in their course, using the environment in their own classrooms as a teaching and learning tool.

**Limitations and recommendations for future work**

It is important to highlight some limitations of this research which open the avenue for future studies. First, the study was conducted amidst a pandemic (COVID-19), where some parts of the experimental settings had to be adjusted. As discussed earlier, due to the building operating hours regulations, it was challenging to accurately measure the electricity and window shade utilization by students in the studios. For instance, before COVID-19, the average time spent in studios by students measured in phase one of the study was over 40 hours per week. After the pandemic, it was around 20-25 hours per week. That amount was already reduced by a half and showed that the building utilization behavior by the occupants is not the same as it was before, and therefore, cannot be a representative of their behavior, but to be considered as temporary action affected by unprecedented regulations. Additionally, following a six-foot social distancing protocol limited the manner of the occupancy for academic buildings. Students' interaction with their teachers and classmates were restricted, creating some challenges to implementing peer-to-peer interaction for especially the Peer PBL group.  Repeating this research in a non-pandemic time can provide a better comparison to of normal building usage.

Second, despite the students' vigorous involvement in class activities in both PBL groups, a lab environment could have resulted in better results. In the comfort assignment students were asked to use basic tools for measuring thermal and lighting conditions. However, in an ideal case, students would be present in the labs and work more collaboratively with their classmates (Peer PBL group) using more accurate measurement equipment. A future research scheme that uses more accurate measurement equipment and enables a comprehensive peer-to-peer interaction is therefore suggested.

As one last future research path, it is suggested that the research be extended to include K-12 communities by adapting the application and studying of the method (in a non-pandemic time) used in this project as a curricular component. The suggested PBL model for k-12 communities can include the activities that require less technical skills for non-technical students towards energy savings and usage of the green building control systems. This may include activities that involve direct interaction of students with the controls and class projects that are devised in a way that students present related research topics to their peers, thereby building an internal teaching-learning mechanism. Moreover, conducting the mentioned full study provides more reliable data (as the surveyor collects the data instead of the students), and in a wider timespan (as students are at school for longer periods of time). The ultimate outcome of the proposed research path is to enhance the understanding of the effects of PBL and peer influence in different age ranges and can contribute to the development of the 'Environmental Comfort and Control' toolkit. As mentioned before, understanding these foundational issues related to comfort, controls, and energy is crucial to green building occupants. If students become informed about these criteria at schools while they are in their early behavior development, undoubtedly further responsibilities will be observed, and more actions will be taken towards energy saving.

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# Appendix

Pre-knowledge Survey

This survey askes APDesign students' knowledge and perceptions of environmental comfort in **two locations:**

- **Design labs (i.e., studio spaces) in the new and renovated portions of the Seaton and Regnier Halls**
- **Their current residences, including on and off campus housing (dorms, apartments, or houses)**

Your participation in the survey will be used to better understand how students perceive and manage environmental comfort, and to evaluate the success of different educational strategies at influencing the use of environmental controls.

Your responses will remain anonymous and the survey will not collect any personal information. The survey is not graded and is not a test or an exam.

Please answer questions impartially and honestly.

The survey is divided into three sections:

I. Questions that pertain to your studio space in Seaton and Regnier Halls
II. Questions that pertain to the place that you currently reside in Manhattan (i.e., dorm, apartment, house)
III. General questions pertaining to your knowledge of environmental controls

## I. Studio Environmental Comfort and Controls

1) Please identify your studio name and number in the box below (i.e., 1147 Seaton Hall, 2123 Regnier Hall). If you do not have studio workstation on campus this semester, please just write "N.A." in the box below and continue on to section II (home environment):

2) Is your studio located in the new section or renovated section of the building? New studios are north of the ‘link’ space shown in yellow below.

   – New

   – Renovated

   –

3) How much time do you typically spend in your studio?

   1. Less than 10 hours per week
   2. 10 to 20 hours per week
   3. 20 to 40 hours per week
   4. 40 to 60 hours per week
   5. More than 60 hours per week

**(Thermal comfort and controls)**

4) Based on your familiarity with your studio, are you aware of the location of the VAV controls? (The VAV controls are small plates with a slider and a “+” and “-“on them.)

   1. Yes

2. No

5) How knowledgeable are you in the operation of the VAV controls in your studio and what they do?
    1. Extremely
    2. Very
    3. Moderately
    4. Slightly
    5. Not at all
6) How knowledgeable are you in recognizing when the appropriate time is to adjust the VAV controls in your studio?
    1. Extremely
    2. Very
    3. Moderately
    4. Slightly
    5. Not at all
7) How satisfied are you typically with the thermal conditions of your studio? Satisfactory thermal conditions are when you do not feel too warm or too cold.
    1. Very satisfied
    2. Satisfied
    3. Neither
    4. Dissatisfied
    5. Very dissatisfied
8) How often do you use the VAV controls in your studio to adjust the temperature?
    1. Very frequently—every day
    2. Occasionally—a few times a week
    3. Sometimes—once a week
    4. Hardly at all—only if there is a serious issue
    5. Never
9) Are you able to recognize when the environment in the studio is too cold or warm?
    1. Yes
    2. Neutral

3. No

10) How do you perceive the current or most recently experienced environment in studio?
    1. Too cold
    2. A little cold
    3. Comfortable
    4. A little warm
    5. Too warm

11) Are you able to recognize when the environment in the studio is too dry or damp?
    1. Yes
    2. Neutral
    3. No

12) I perceive the air to be __________ when I am in the studio:
    1. Too dry
    2. Just right- not too dry or too damp
    3. Too damp

13) Are you able to recognize when the air in the studio is fresh or stale?
    1. Yes
    2. Neutral
    3. No

14) I perceive the air to be _________ when I am in the studio:
    1. Fresh
    2. Stale

15) I perceive the air is _______ when I am in the studio:
    1. Moving
    2. Still

16) I open or close the operable windows to increase ventilation in the studio:
    1. Strongly agree
    2. Agree
    3. Neutral
    4. Disagree
    5. Strongly disagree

17) I wear outer wear or additional clothing indoors when it is too cold in the studio:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

18) I wear shorts, short sleeves, open shoes (ex. Flip-flops), or other summer clothing when it is too warm in studio:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

19) I use blankets when it is too cold in the studio:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

20) If I changed position in the room, my thermal comfort would improve:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

21) I believe my clothing is helping me to feel more comfortable in my space in the studio:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

22) I am aware that if I stay in my space for an extended period of time, I will acclimate [get used] to the thermal condition in the space:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

**(Visual comfort and lighting controls)**

23) Are you aware of the location of the lighting and dimming controls in your studio?

1. Yes
2. No

24) How knowledgeable are you in the operation of the lighting and dimming controls in your studio?

1. Extremely
2. Very
3. Moderately
4. Slightly
5. Not at all

25) How knowledgeable are you in recognizing when the appropriate time is for manipulating the lighting and dimming controls in your studio?

1. Extremely
2. Very
3. Moderately
4. Slightly
5. Not at all

26) For this question, please select number 3:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree

5. Strongly disagree

27) How satisfied typically are you with the light quality of your studio? Light quality is satisfactory when you can comfortably and accurately see the visual task you are performing without interference from glare.

1. Very satisfied
2. Satisfied
3. Neither
4. Dissatisfied
5. Very satisfied

28) How strongly do you agree or disagree with this statement: “The window shades in the studio significantly improve the light quality of the space”?

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

29) If window shades are available near your workstation in the studio, how often do you move/control them?

1. Very frequently—every day
2. Occasionally—a few times a week
3. Sometimes—once a week
4. Hardly at all—only if there is a serious issue
5. Never

30) How often do you use the lighting controls in your studio to turn the lights on or off?

1. Very frequently—every day
2. Occasionally—a few times a week
3. Sometimes—once a week
4. Hardly at all—only if there is a serious issue
5. Never

31) How often do you use the dimming controls in your studio to adjust (increase or decrease) the amount of illumination provided by the lighting?

1. Very frequently
2. Occasionally—a few times a week
3. Sometimes—once a week
4. Hardly at all-o only if there is a serious issue
5. Never

32) I am that kind of person who turns off the lights in the studio when no one is there:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

33) I am that kind of person who turns the lights off when I realize I am the last person leaving the studio:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

34) I am that kind of person who may ask the people in studio if they'd like the lights dimmed or turned off when I realize that only a few people are left in the studio:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

35) I turn the lights on or up when it is too dark in the studio:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

36) I turn the lights down or off when it is too bright in the studio:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

37) I lower the window shades when it is too bright or there is too much glare in the studio:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

38) I raise the shades to increase daylight in the studio:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

39) I lower the shades because I need to have privacy in my space in the studio:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

40) For this question, please select number 5:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

41) I use a personal lamp or other light source at my desk to improve visual comfort at my desk:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

42) I change the orientation of my workspace but stay in my current location to deal with visual comfort issues that I am experiencing in my studio:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly agree

43) If I moved my workspace to a new location in studio, it would improve my visual comfort in the studio:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

44) I am that kind of person who, if closing the shades in the studio to address a temporary visual comfort issue (like glare from the morning sun), would raise them again later when visual comfort allows:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

45) I am aware that my lighting comfort will improve with time in space:

1. Strongly agree

2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

## II. Home Environmental Comfort and Controls

46) How satisfied are you typically with the thermal conditions of your dorm/apartment/house? Thermal conditions are satisfactory when you do not feel too warm or too cold.
    1. Very satisfied
    2. Satisfied
    3. Neither
    4. Dissatisfied
    5. Very dissatisfied
47) How do you perceive the current environment in your dorm/apartment/house?
    1. Too cold
    2. A little cold
    3. Comfortable
    4. A little warm
    5. Too warm
48) Are you able to recognize when the environment in your dorm/apartment/house is too dry or damp?
    1. Yes
    2. Neutral
    3. No
49) I perceive the air feels __________ when I am in my dorm/apartment/house:
    1. Too dry
    2. Just right- not too dry or too damp
    3. Too damp
50) Are you able to recognize when the environment in your dorm/apartment/house is fresh or stale?

1. Yes
2. Neutral
3. No

51) I perceive the air feels ________ when I am in my dorm/apartment/house:
1. Fresh
2. Stale

52) I perceive the air is ______ when I am in my dorm/apartment/house:
1. Moving
2. Still

53) How frequently do you manipulate the thermostat in your home?
1. Very frequently—every day
2. Occasionally—a few times a week
3. Sometimes – once a week
4. Hardly at all – only if there is a serious issue
5. Not at all

54) What is the current temperature set point (i.e. setting) on your thermostat?
1. The current temperature setpoint is ______
2. I do not know how to read the setpoint from the thermostat
3. I do not control the temperature in my dorm/apartment/house (there is no thermostat in my living space)

55) Are your HVAC systems running either right now or in the last 24 hours?
1. No—it is not or has not been running
2. Yes—air conditioning
3. Yes—heating
4. I do not know if the HVAC systems are running or not

56) How satisfied typically are you with the light quality of your dorm/apartment/house? Light quality is satisfactory when you can see the visual task you are performing without interference from glare.
1. Very satisfied
2. Satisfied

3. Neither
4. Dissatisfied
5. Very satisfied

57) How frequently do you manipulate the window shades in your home?
  1. Very frequently—every day
  2. Occasionally—a few times a week
  3. Sometimes—once a week
  4. Hardly at all—only if there is a serious issue
  5. Never

58) Do you use fans in your dorm/apartment/ house to increase comfort?
  1. Yes
  2. No

59) What is the typical status of the window coverings (shades, blinds, or drapes) in your dorm/apartment/house during the daytime?
  1. Window coverings are up or open
  2. Window coverings are ‘shear’ or mostly translucent; they are down but some daylight still gets through them
  3. Window coverings are down or closed, and most of the daylight is blocked
  4. NA

60) How often do you use electric lights during daylight hours in your dorm/apartment/house?
  1. Most of the day
  2. Frequently
  3. Just for short periods
  4. Rarely
  5. We never turn on electric lights during daylight hours

61) Is the daylight in your dorm/apartment/house sufficient for normal activities without electric light?
  1. Yes
  2. Sometimes, dependent on outdoor lighting conditions
  3. No

## III. General Information

62) I use environmental controls in Seaton and Regnier Halls in a way that conserves energy:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly agree

63) I use environmental controls at home in a way that conserves energy:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly agree

64) I believe that there has been enough information provided by the school administration on the appropriate use of the environmental controls in Seaton and Regnier Halls:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly agree

65) My friends in my social network influence how I use environmental controls:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

66) My classmates (i.e. people you are in classes or studio with) influence how I use environmental controls:

6. Strongly agree
7. Agree
8. Neutral

9. Disagree
10. Strongly disagree

67) I share my knowledge and understanding of environmental controls in Seaton and Regnier Halls with my friends and classmates:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

68) I share my knowledge and understanding of environmental controls with friends or roommates in my housing at KSU/Manhattan:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly agree

69) I share my knowledge and understanding of environmental controls with my family at home (where I reside when I am not at KSU/Manhattan):

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

70) Please identify your lab section by your lab leader's name. You can see your lab section on Canvas by checking the announcement made on 8/25/2020 or by checking your group listing in the 'Lab Groups' set.

1. Gibson
2. Demuth
3. Cresswell

**THANK YOU**

Follow-up survey question sets

**Follow-up survey**

Thank you for your participation in our research project during the month of August, in which we were studying the success of different interventions in increasing and evaluating students' knowledge and perceptions on environmental comfort in two locations: Design labs (i.e. studio spaces) and their current residences (i.e. off and on campus housing).

We hope that you can spend just a few minutes to answer the following questions regarding the activities in your class and how it impacted your awareness or knowledge of, actions, and decisions related to comfort and environmental controls. Your responses will remain anonymous and we ask you to be impartial and honest. Consider the questions to apply to either/or the design labs (studio spaces) in Seaton and your residence.

Please do not write your name on this page.

| |
|---|
| The class activities in which your group participated were: Project-based Learning Module (Comfort Lecture, Comfort Lab Assignment, Group Discussion Board, and Peer-to-Peer Presentations in Zoom)<br>In the survey, "class activities" refers generally to all of these above activities. |

1. How did the class activities impact your use of light controls (on/off, dimming) in your space (home/studio)?

1) No impact—class activities did not affect how and if I used these controls
2) Moderate impact— class activities increased my occasional use of these controls
3) Strong impact— class activities increased my use of these controls so that I use them daily

2. How did the class activities impact your use of thermal controls (+/- thermostat overrides) in your space (home/studio)?

1) No impact— class activities did not affect how and if I used these controls
2) Moderate impact— class activities increased my occasional use of these controls
3) Strong impact—class activities increased my use of these controls so that I use them daily

3. How did the class activities impact your use of window shades in your space (home/studio)?

1) No impact—class activities did not affect how and if I used these controls
2) Moderate impact— class activities increased my occasional use of these controls
3) Strong impact— class activities increased my use of these controls so that I use them daily

4. How did the class activities impact your use of task lighting: a personal light at your desk (home/studio)?

1) No impact— class activities did not affect how and if I used these controls
2) Moderate impact— class activities increased my occasional use of these controls
3) Strong impact— class activities increased my use of these controls so that I use them daily

5. How knowledgeable are you *now* in the operation of the lighting and dimming controls either at your home or studio, versus what you reported in August?

1) Extremely
2) Very
3) Moderately
4) Slightly
5) Not at all

6. How knowledgeable are you *now* in the operation of the thermostat overrides either at your home or studio, versus what you reported in August?

1) Extremely
2) Very
3) Moderately
4) Slightly
5) Not at all

7. To what extent were your classmates were helpful in reinforcing or informing new knowledge regarding the comfort assignment?

1) Extremely
2) Very

3) Moderately
4) Slightly
5) Not at all

8. Following the things that you have learned in class, how likely will you be to share your knowledge and understanding of controls with your friends and family the next time you are given the opportunity?

6) Extremely
7) Very
8) Moderately
9) Slightly
10) Not at all

9. Following the things that you have learned in class, how likely will you be to advise your parents' usage of the controls at your parents' home?

1) Extremely
2) Very
3) Moderately
4) Slightly
5) Not at all

10. To what extent do you manipulate the controls in your current residence (apartment, dorm, house, etc.)?

1) Extremely
2) Very
3) Moderately
4) Slightly
5) Not at all

11. To what extent did the group discussions on Canvas and Zoom meetings with your teammates increase your knowledge of building controls and influencing your decisions of "when and how" to use them?

1) Extremely
2) Very
3) Moderately
4) Slightly
5) Not at all

12. To what extent did the group discussions on Canvas and Zoom calls with your teammates increase your awareness in better understanding and identifying the environmental discomfort in your space (home/studio)?

1) Extremely
2) Very
3) Moderately
4) Slightly
5) Not at all

13. After the class activities, which reasons are the most vs. the least important to you for using controls (light switches, thermal overrides, window shades)? Rank the following four rationale (1=most important to 4= least important):

___Minimizing the energy costs at my home

___Conserving energy

___Minimizing greenhouse gas emissions

___Ensuring, improving, or maintaining my personal comfort

14. After the class activities, who/what influences your use of controls (light switches, thermal overrides, window shades) the most vs. the least? Rank the following four rationales (1=most influence to 5=little or no influence):

___Your studio teacher

___The class activities (lectures, assignments, discussions) you have completed in ESA.

___A studio classmate who is not part of your social group (i.e. people I spend time with outside of studio)

___A studio classmate in my class group

___A studio classmate from a different studio

___Me: If I chose to increase my use of controls, I did it for my own reasons

15. How much effective and beneficial do you believe the "Self-Reflection" report was regarding your learning?

1) Extremely
2) Very
3) Moderately
4) Slightly
5) Not at all

**THANKS**

**Follow-up survey**

Thank you for your participation in our research project during the month of August, in which we were studying the success of different interventions in increasing and evaluating students' knowledge and perceptions on environmental comfort in two locations: Design labs (i.e., studio spaces) and their current residences (i.e., off and on campus housing).

We hope that you can spend just a few minutes to answer the following questions regarding the activities in your class and how it impacted your awareness or knowledge of, actions, and decisions related to comfort and environmental controls. Your responses will remain anonymous and we ask you to be impartial and honest. Consider the questions to apply to either/or the design labs (studio spaces) in Seaton and your residence.

Please do not write your name on this page.

| |
|---|
| The class activities in which your group participated were: Project-based Learning Module (Comfort Lecture, Comfort Lab Assignment, Group Discussion Board)<br>In the survey, "class activities" refers generally to all of these above activities. |

1. How did the class activities impact your use of light controls (on/off, dimming) in your space (home/studio)?

4) No impact—class activities did not affect how and if I used these controls
5) Moderate impact— class activities increased my occasional use of these controls
6) Strong impact— class activities increased my use of these controls so that I use them daily

2. How did the class activities impact your use of thermal controls (+/- thermostat overrides) in your space (home/studio)?

4) No impact— class activities did not affect how and if I used these controls
5) Moderate impact— class activities increased my occasional use of these controls
6) Strong impact—class activities increased my use of these controls so that I use them daily

3. How did the class activities impact your use of window shades in your space (home/studio)?

4) No impact—class activities did not affect how and if I used these controls
5) Moderate impact— class activities increased my occasional use of these controls
6) Strong impact— class activities increased my use of these controls so that I use them daily

4. How did the class activities impact your use of task lighting: a personal light at your desk (home/studio)?

4) No impact— class activities did not affect how and if I used these controls
5) Moderate impact— class activities increased my occasional use of these controls
6) Strong impact— class activities increased my use of these controls so that I use them daily

5. How knowledgeable are you *now* in the operation of the lighting and dimming controls either at your home or studio, versus what you reported in August?

6) Extremely
7) Very
8) Moderately
9) Slightly
10) Not at all

6. How knowledgeable are you *now* in the operation of the thermostat overrides either at your home or studio, versus what you reported in August?

6) Extremely
7) Very
8) Moderately
9) Slightly
10) Not at all

7. To what extent were your classmates were helpful in reinforcing or informing new knowledge regarding the comfort assignment?

11) Extremely
12) Very
13) Moderately
14) Slightly
15) Not at all

8. Following the things that you have learned in class, how likely will you be to share your knowledge and understanding of controls with your friends and family the next time you are given the opportunity?

16) Extremely
17) Very
18) Moderately
19) Slightly
20) Not at all

9. Following the things that you have learned in class, how likely will you be to advise your parents' usage of the controls at your parents' home?

6) Extremely
7) Very
8) Moderately

9) Slightly
10) Not at all

10. To what extent do you manipulate the controls in your current residence (apartment, dorm, house, etc.)?

6) Extremely
7) Very
8) Moderately
9) Slightly
10) Not at all

11. To what extent did the group discussions on Canvas your teammates increase your knowledge of building controls and influencing your decisions of “when and how” to use them?

6) Extremely
7) Very
8) Moderately
9) Slightly
10) Not at all

12. To what extent did the group discussions on Canvas with your teammates increase your awareness in better understanding and identifying the environmental discomfort in your space (home/studio)?

6) Extremely
7) Very
8) Moderately
9) Slightly
10) Not at all

13. After the class activities, which reasons are the most vs. the least important to you for using controls (light switches, thermal overrides, window shades)? Rank the following four rationale (1=most important to 4= least important):

___Minimizing the energy costs at my home

___Conserving energy

___Minimizing greenhouse gas emissions

___Ensuring, improving, or maintaining my personal comfort

14. After the class activities, who/what influences your use of controls (light switches, thermal overrides, window shades) the most vs. the least? Rank the following four rationales (1=most influence to 5=little or no influence):

___Your studio teacher

___The class activities (lectures, assignments, discussions) you have completed in ESA.

___A studio classmate who is not part of your social group (i.e., people I spend time with outside of studio)

___A studio classmate in my class group

___A studio classmate from a different studio

___Me: If I chose to increase my use of controls, I did it for my own reasons

15. How much effective and beneficial do you believe the “Self-Reflection” report was regarding your learning?

6) Extremely
7) Very
8) Moderately
9) Slightly
10) Not at all

**THANKS**

**Follow-up survey**

Thank you for your participation in our research project during the month of August, in which we were studying the success of different interventions in increasing and evaluating students' knowledge and perceptions on environmental comfort in two locations: Design labs (i.e., studio spaces) and their current residences (i.e., off and on campus housing).

We hope that you can spend just a few minutes to answer the following questions regarding the activities in your class and how it impacted your awareness or knowledge of, actions, and decisions related to comfort and environmental controls. Your responses will remain anonymous and we ask you to be impartial and honest. Consider the questions to apply to either/or the design labs (studio spaces) in Seaton and your residence.

Please do not write your name on this page.

| |
|---|
| The class activities in which your group participated were: Traditional Learning Module (Comfort Lecture)<br>In the survey, "class activities" refers generally to all of these above activities. |

1. How did the class activities impact your use of light controls (on/off, dimming) in your space (home/studio)?

7) No impact—class activities did not affect how and if I used these controls
8) Moderate impact— class activities increased my occasional use of these controls
9) Strong impact— class activities increased my use of these controls so that I use them daily

2. How did the class activities impact your use of thermal controls (+/- thermostat overrides) in your space (home/studio)?

7) No impact— class activities did not affect how and if I used these controls
8) Moderate impact— class activities increased my occasional use of these controls
9) Strong impact—class activities increased my use of these controls so that I use them daily

3. How did the class activities impact your use of window shades in your space (home/studio)?

7) No impact—class activities did not affect how and if I used these controls
8) Moderate impact— class activities increased my occasional use of these controls
9) Strong impact— class activities increased my use of these controls so that I use them daily

4. How did the class activities impact your use of task lighting: a personal light at your desk (home/studio)?

7) No impact— class activities did not affect how and if I used these controls
8) Moderate impact— class activities increased my occasional use of these controls
9) Strong impact— class activities increased my use of these controls so that I use them daily

5. How knowledgeable are you *now* in the operation of the lighting and dimming controls either at your home or studio, versus what you reported in August?

11) Extremely
12) Very
13) Moderately
14) Slightly
15) Not at all

6. How knowledgeable are you *now* in the operation of the thermostat overrides either at your home or studio, versus what you reported in August?

11) Extremely
12) Very
13) Moderately
14) Slightly
15) Not at all

7. To what extent were your classmates were helpful in reinforcing or informing new knowledge regarding the comfort lecture?

21) Extremely
22) Very
23) Moderately
24) Slightly
25) Not at all

8. Following the things that you have learned in class, how likely will you be to share your knowledge and understanding of controls with your friends and family the next time you are given the opportunity?

1) Extremely likely
2) Somewhat likely
3) Neither likely nor unlikely
4) Somewhat unlikely
5) Extremely unlikely

9. Following the things that you have learned in class, how likely will you be to advise your parents' usage of the controls at your parents' home?

6) Extremely likely
7) Somewhat likely
8) Neither likely nor unlikely

9) Somewhat unlikely
10) Extremely unlikely

10. To what extent do you manipulate the controls in your current residence (apartment, dorm, house, etc.)?

11) Extremely
12) Very
13) Moderately
14) Slightly
15) Not at all

11. To what extent did the comfort lecture increase your knowledge of building controls and influencing your decisions of “when and how” to use them?

11) Extremely
12) Very
13) Moderately
14) Slightly
15) Not at all

12. To what extent did the comfort lecture increase your awareness in better understanding and identifying the environmental discomfort in your space (home/studio)?

11) Extremely
12) Very
13) Moderately
14) Slightly
15) Not at all

13. After the comfort lecture, which reasons are the most vs. the least important to you for using controls (light switches, thermal overrides, window shades)? Rank the following four rationale (1=most important to 4= least important):

___Minimizing the energy costs at my home

___Conserving energy

___Minimizing greenhouse gas emissions

___Ensuring, improving, or maintaining my personal comfort

14. After the comfort lecture, who/what influences your use of controls (light switches, thermal overrides, window shades) the most vs. the least? Rank the following four rationales (1=most influence to 5=little or no influence):

___Your studio teacher

___The class activities (comfort lecture) you have completed in ESA.

___A studio classmate who is not part of your social group (i.e. people I spend time with outside of studio)

___A studio classmate in my class group

___A studio classmate from a different studio

___Me: If I chose to increase my use of controls, I did it for my own reasons

**THANKS**

Self-reflection report (template)

BUCK INSTITUTE FOR EDUCATION
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## SELF-REFLECTION PROJECT WORK

| Reflect on the work that you did in this project. Write your comments in the right column. | |
|---|---|
| Basic learning objective of the project: | |
| List the major steps of the project: | |
| About Yourself: | |
| What is the most important thing you learned in this project: | |
| What do you wish you had spent more time on or done differently: | |
| What part of the project did you do your best work on: | |
| About the Project: | |
| What was the most enjoyable part of this project: | |
| What was the least enjoyable part of this project: | |
| How could your teacher(s) change this project to make it better next time: | |

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