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Contents

Volume 18, No. 5, September – October 2023

Page

Prototype of household compost bin turns food waste into compost for residents in a personnel condominium of Yala Rajabhat University 1
Piyaruk Pradabphetrat,Saudee Maprasit,Montakarn Pimsen,Warin Narawit and Sidthipong Sathawong

Participatory Management for Sustainable Low-Carbon Community: A Case Study in Pa Pae Village, Mae Hong Son Province, Thailand 9
Piyaruk Pradabphetrat,Saudee Maprasit,Montakarn Pimsen,Warin Narawit and Sidthipong Sathawong

Promoting EFL Thai Undergraduates' Reading Comprehension and Reading Motivation through Extensive Reading 16
Pasika Tantipidok

Exploring Ergonomic Risk Factors and Discomfort Levels in Work-from-Home Settings: A Study during the COVID-19 Pandemic 22
Worrawit Nakpan,Pathanin Sangaroon,Anunya Pradidthaprecha,Kultida Bunjongsiri, Araya Prasertchai ,Pokkamol Laoraksawong and Saruda Jiratkulthana

Methodological Framework for Evaluating Cost-Effective Energy and Climate Measures in Building Clusters 29
Suparatchai Vorarat,Watcharapong Tantawat,Prayuth Rittidatch and Aumnad Phdungsilp

Causal Model of Environmental Conservation Behaviors of Praboromarajchanok Institute Students 37
Paisit Jirarattanasopa,Piyaruk Pradabphetrat and Vichit Rangpan

Social Welfare Policy for Prevention and Factors Influencing the Use of Tramadol by School Children and Adolescents in Thailand. 46
Benjaporn Buasumlee and Jaturong Boonyarattanasoontorn

Digital Logic Gate Simulation in Computer and IT for Agricultural Agricultural Communications Course 54
Kataya Mahachanawong Suvarnaphaet and Phisit Suvarnaphaet

Editorial Note

The Interdisciplinary Research Review (IRR) was established with academic cooperation by The Royal Society of Thailand Committee of Interdisciplinary Research and Development, Rajabhat University (Western Group), and Rajamangala University of Technology Rattanakosin. This Issue, Volume 18 Number 5 (September – October 2023). This issue contains of four interesting articles in multidisciplinary fields: (1) Prototype of household compost bin turns food waste into compost for residents in a personnel condominium of Yala Rajabhat University , (2) Participatory Management for Sustainable Low-Carbon Community: A Case Study in Pa Pae Village, Mae Hong Son Province, Thailand, (3) Promoting EFL Thai Undergraduates' Reading Comprehension and Reading Motivation through Extensive Reading, (4) Exploring Ergonomic Risk Factors and Discomfort Levels in Work-from-Home Settings: A Study during the COVID-19 Pandemic, (5) Methodological Framework for Evaluating Cost-Effective Energy and Climate Measures in Building Clusters, (6) Causal Model of Environmental Conservation Behaviors of Praboromarajchanok Institute Students, (7) Title Social Welfare Policy for Prevention and Factors Influencing the Use of Tramadol by School Children and Adolescents in Thailand, and (8) Digital Logic Gate Simulation in Computer and IT for Agricultural Communications Course.

The Editorial Board of the IRR encourages anyone to submit articles for evaluation and review. The processes of submission, review and publication of articles are described on the journal's website, https://www.tci-thaijo.org/index.php/jtir. The Editorial Board and Committees of the IRR sincerely thank all peer reviewers who have sacrificed their time to help us produce a better journal, and also wish to thank all teachers, researchers and other academicians for submitting their valuable research to this journal. Finally, we thank readers of our journal who help to spread the knowledge and benefits gained to others. With your feedback and suggestions, we will strive to improve the quality and relevance of the IRR.

Yongyudh Vajaradul
Editor
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Prototype of household compost bin turns food waste into compost for residents in a personnel condominium of Yala Rajabhat University

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Abstract

This research was to study the design guidelines for a prototype of the household compost bin for the residents of the personnel condominium of Yala Rajabhat University and to analyze the macronutrient contents of compost from the household compost bin. The questionnaire was used to interview residents in the personnel condominium to explore information about the type, quantity, and management of solid waste and to study the feasibility of developing a prototype of the household bin to turn food waste into compost. The results revealed that most households in the personnel condominium collected the solid waste without sorting or disposing of the waste in the same container. The amount of organic waste that needs to be disposed of is about 0.5-1 kg per day, including food scraps, e.g., rice scraps, snack scraps, vegetable scraps, and fruit peels. The residents opined that sorting food scraps before throwing them out is not a burden. They agreed that the household compost bin was available for use in the area of the personnel condominium. Therefore, the researchers have designed a household compost bin made from a 200-liter HDPE polypropylene plastic tank, placed it vertically on a steel stand, and installed stirrers inside the tank. After that, household organic waste was composted to make fertilizer with organic waste materials, consisting of rice husks, coconut coir dust, and small dry leaves. Then, the Super LDD 1 microbial activator of the Land Development Department was added to assess the efficiency of the household compost bin. The composting of household organic waste in the compost bin for 30 days revealed that the compost is soft, crumbly, easily torn, smells like soil, and the color of fermented material is dark brown. The composts obtained from the 3 different fermented materials demonstrated that the amount of moisture, pH value, electrical conductivity, amount of organic matter, organic carbon, C/N ratio, total nitrogen content, total phosphorus, and total potassium met the organic fertilizer standard of the Department of Agriculture, Thailand. Consequently, quality compost can be used as a soil amendment.

Keywords: food waste, compost, household compose bin

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1. Introduction

Currently, the problem of community solid waste in Thailand is urgent. It is an issue that needs to be properly addressed due to the production of large volumes of solid waste, which tends to increase every year while the areas of waste disposal sites are limited and local government organizations responsible for the management of solid waste have limited budgets and personnel. Thus, all of the solid waste cannot be properly disposed of according to sanitation principles and may cause environmental pollution problems, sources of disease vectors, nuisances, impacts on the economy of the country, and public health problems. Therefore, solid waste management guidelines should focus on reducing the amount of solid waste at the source by promoting and supporting the reuse of solid waste before disposing of it at the waste disposal site [1]. More than 50 percent of solid waste is food waste, vegetables, and fruits, which are often not managed properly and become breeding grounds for germs, emitting bad odor, and generating methane, causing environmental problems, including being one of the major causes of global warming [2].

The sorting and utilizing organic waste are ways to reduce solid waste, such as organic composting, biofermented water for soil nourishment in agriculture, biogas production to replace fuel energy, and animal feed. The solid waste that can be composted is food waste, vegetables, fruits, leaves, twigs, animal manure, sludge from wastewater treatment systems, sawdust, etc. [3]. Composting is a waste management op-

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tion suitable for limited resources in developing countries. It is also an environmentally friendly approach that avoids all pollution problems. One of the benefits of compost comes from the use of microorganisms to decompose organic waste into nutrients and produce organic fertilizers [4]. Compost is a soil conditioner because adding compost to the soil improves soil structure, chemical composition, and biological properties that make soil conditions suitable for plant growth, such as increasing soil aeration and water retention capacity, and providing a source of micronutrients necessary for plant growth [3]. Yala Rajabhat University attaches great importance to the environment according to the policy of university development toward a green university (Green YRU) since 2018. The implementation of the Green YRU project showed that the amount of solid waste in the university has increased, which affected the environment and created bad smell and negative images and scenery of the university. Also, the solid waste problem lacks systematic action for collecting, sorting, potential waste recycling, and disposing of solid waste. The university has taken the first step to solve this problem by providing adequate waste bins inside and outside the building. In addition, there was a campaign for students and staff to realize the importance of separating and disposing of solid waste into different containers provided and segregating solid waste for proper management and further use, such as compost to nourish the soil and trees in the university. This can reduce the use of chemicals or chemical fertilizers, be cost-saving, increase the value of solid waste, and help to preserve the environment in the university. This led to the concept of a study to survey the situation of solid waste in the personnel condominium of Yala Rajabhat University in order to know the basic information about the type, quantity, and management of solid waste by using a questionnaire to collect data from the relevant target groups who live in the personnel condominium. These data were used to study the feasibility of developing a prototype of a household compost bin to convert food waste into fertilizer. Consequently, the main aim of this study was to study the design guidelines for a prototype of the household compost bin for the residents of the personnel condominium of Yala Rajabhat University. It also analyzes the macronutrient contents of compost from the household compost bin. Moreover, this study provides rich information for studying and designing a prototype of the household compost bin to produce compost from compostable raw materials that add nutrients to the soil and help improve soil quality. Furthermore, the use of waste organic materials provides an alternative for communities and industries to produce environmentally friendly compost.

2. Materials and methods

2.1 The design guidelines for a prototype of the household compost bin for the residents in the personnel condominium of Yala Rajabhat University

2.1.1 A survey of the type, quantity, and management of solid waste in the personnel condominium of Yala Rajabhat University

This is a situational survey study about the type, quantity, and management of solid waste in the area of the personnel condominium of Yala Rajabhat University. The population in this study was the residents of the personnel condominium of Yala Rajabhat University, consisting of 44 studio-type rooms and 53 unit-type rooms. In this study, the whole population was used as a sample group for data collection. The questionnaire was used to interview relevant target groups, which are the residents of the personnel condominium. Data were used for a feasibility study in the preparation of a prototype of the household compost bin that turns food waste into compost. The collected data were analyzed using descriptive statistics, e.g., frequency and percentage. The content analysis was also used to describe other suggestions or comments from the target groups.

2.1.2 Prototype design of the household compost bin for residents in the personnel condominium of Yala Rajabhat University

From the results of the preliminary questionnaire study, the relevant target groups are the residents of the personnel condominium. Thus, the prototype of the household compost bin was designed by referring to the household composter [5], which can be used in houses with about 4-5 residents. In this study, aerobic compositing was selected to produce organic material that is useful for plants, called humus. Organic waste or household biodegradable waste, e.g., food scraps and fruit and vegetable scraps were fermented with residual organic materials that can be obtained locally (i.e., rice husks, coconut coir dust, and small dry leaves) at a ratio of 60:40 by weight, and 10 grams of the Super LDD 1 Microbial Activator of the Land Development Department were added. The 3 treatments consisted of 1) organic waste + rice husks + LDD 1, 2) organic waste + coconut coir dust + LDD 1, and 3) organic waste + small dry leaves + LDD 1. The initial humidity of the fermented material was controlled to be in the range of 50-60%. Physical and chemical changes, including temperature inside the tank, the amount of moisture, and pH value, were measured every two days during the study to evaluate the efficiency of the household compost bin.

2.2 Analysis of the macronutrient contents of compost from the household compost bin

This experiment studied the organic waste composting. At the end of the 30-day fermentation pe-

riod, the compost was removed from the compost bin. The samples were analyzed for physical and chemical properties, including the macronutrient quantity in the laboratory. The samples of compost from 3 treatments were analyzed to evaluate the suitable quality of household compost for recycling as fertilizer, including temperature, moisture content, pH value, electrical conductivity (EC), organic matter (OM), organic carbon (OC), C/N ratio, total nitrogen content (N), total phosphorus (P), and total potassium (K).

3. Results and discussion

3.1 The design guidelines for a prototype of the household compost bin for the residents in the personnel condominium of Yala Rajabhat University

3.1.1 A survey of the type, quantity, and management of solid waste in the personnel condominium of Yala Rajabhat University

The results of a survey of preliminary information about the type, quantity, and management of solid waste by residents in the personnel condominium of Yala Rajabhat University indicated that most of the respondents throw all types of waste directly into the household bins. Most of the households had an amount of organic waste that had to be disposed of each day about 0.5-1 kilogram. The types of organic waste that occur in the household on a daily basis are food waste, rice or snack scraps, vegetable scraps or fruit peels, meat scraps, e.g., pork, fish, shrimp, crab shells, fishbones, chickens, eggshells, leaves or branches, and others. The majority of the respondents commented that sorting food waste before discarding was not a burden because it was easy to do. They agreed that there was a dedicated and readily available household compost bin in the personnel condominium. Consequently, the researchers have designed a household compost bin that is suitable for the residents of the personnel condominium of Yala Rajabhat University.

According to the results of this study, some residents in the personnel condominium have sorted and reused the solid waste in various ways, causing less household waste to be disposed of. The operant conditioning theory of Skinner [6] stated that the relationship between behavior and the environment (the stimuli that cause the behavior and the result of that behavior) may be due to multiple environments not conducive to the separation of solid waste, such as a lack of containers for separating solid waste, improper segregation of solid waste, ignorance of the benefits of waste segregation. Moreover, some people think that it is not their duty to separate solid waste. Nonetheless, these behaviors can be changed by promoting or educating people about the benefits and harms of solid waste to create awareness of the problem or incentives for the public to provide more garbage containers. As a result, people can separate more solid waste through the recycling waste bank project. Good awareness can be created by giving people knowledge about solid waste reduction and segregation and appreciation of solid waste value in generating income for people in the community, resulting in awareness and participation in environmental stewardship [6]. Hence, Yala Rajabhat University should continuously organize activities or take action on solid waste management by raising conscience or awareness about solid waste management in all sectors. Moreover, there are guidelines for managing solid waste from the beginning to the end by using the 3R principles (reduce, reuse, and recycle).

3.1.2 Prototype design of the household compost bin for residents in the personnel condominium of Yala Rajabhat University

The household compost was made from a 200-liter HDPE polypropylene plastic tank of 45 cm in diameter and 100 cm in height and placed vertically on a steel stand. The 7-layer pitched-blade turbine was installed inside the tank with a rotating handle, and the blades have a tilt angle of 30 degrees. Around the compost bin, the holes were drilled about 0.3 cm in diameter to allow outside air to flow into the compost bin at all times, which maintains an aerobic composting environment. Two holes were drilled in the top lid of the tank, approximately 15 x 40 cm, for filling the fermentation materials into the tank. The bottom part of the tank was drilled to an opening-closing size of 20 x 45 cm for removing compost from the compost bin. This tank was designed to operate in a semi-continuous system. At the end of the fermentation period, the pre-fed fermented materials were removed first, and the next fermented materials were replaced.

Physical and chemical analysis results of compost from the compost bin, which is obtained from waste organic material used as a composting medium for three types of fertilizers (rice husks, coconut coir dust, and small dry leaves). The results of the fermentation materials from the bottom layer of the compost bin are shown as follows:

Temperature: The temperature changes in the compost bin were measured every 2 days throughout the experimental period. The results demonstrated that the temperature was affected during the fermentation process in all three experiments (Figure 1), showing an increase in temperature during the 2-7 days of fermentation. The initial temperature increase was due to microbial metabolism and growth in the early stage of fermentation, which caused more microbial degradation [7, 8, 9]. Moreover, there is an exothermic process from decomposing organic matter [10], resulting in heat accumulation inside the compost. Over time the temperature of the compost gradually decreases due to some microorganisms beginning to die. Therefore, the amount of organic matter is completely decomposed,

causing the decrease of temperature. The temperature is stabilized when complete decomposition has occurred. The composting period was approximately 30 days, after that the temperature of the compost was stable and close to room temperature [8]. In addition, it seemed that the temperature in the compost bin was not higher than 60°C, which is the range of temperature that can destroy pathogens in the compost [11]. This is because the compost bin was designed with a pitched-blade turbine for inverting the fermented material and for ventilating the heat accumulated from microbial degradation activities while the blades are rotating, resulting in a higher rate of biodegradation of organic waste [12]. Moreover, continuous fermentation feeding allows partial mixing of new and old fermented materials, causing the transfer of heat from decomposition to the environment. Nevertheless, the change in temperature of the fermented materials in the compost bin still tends to increase and decrease according to general composting [5].

Moisture content: The fermentation in this compost bin was continuously added to the fermented materials daily, with the initial moisture content controlled to be in the range of 50-60%. Water was not added throughout the experiment. The moisture content in the compost bin is within the range that can be composted by the liquid produced by the degradation activity of the continuously fed fermentation materials, and the ventilation in the bin is not excessive to the extent that it loses moisture. The change in moisture content of the fermented material was measured every 2 days throughout the experimental period (Figure 2). On the first day of the 3 treatments, the moisture content of the fermentation material was in the range of 55-75%. It is because the fermented materials used in the experiment were food scraps, fruits, and vegetables, which were organic materials with high moisture content. The bottom of the compost bin had to be waterlogged and when sampled for analysis, it looked muddy. The high moisture content in the compost bin could lead to anaerobic conditions and a longer composting process [11, 13]. The fermentation process increases the moisture content of the compost bin because the fermented material is dehydrated by the decomposition reaction. It can be seen that the dehydration rate is high during days of high temperatures in the compost bin or days of high degradation activity. Thereafter, the moisture content gradually decreases, whereas the decrease in moisture content during fermentation is one of the indexes indicating degradation activity due to the heat generated by decomposition leading to the evaporation of water in the fermentation material and the use by microorganisms [5, 14]. Proper moisture content is essential for microbial growth and is an important factor in fermentation for microbial degradation and nutrient transfer in chemical reactions. In cases where the moisture content of the compost is too high (¿70%), it will hinder the airflow inside the compost bin (blocking the oxygen from entering the gaps in the fermentation material), which can lead to nutrient oxygen depletion and anaerobic fermentation with low degradation reactions. On the other hand, if the moisture content is too low (¡30%), the airflow rate is insufficient for the biochemical degradation reaction to carry out thoroughly because microorganisms lack water. Consequently, microbial activity decreases and goes into a dormant state, causing the microorganisms to be unable to propagate species [5, 14, 15, 16]. The most preferable moisture content for composting ranges from 40 to 60% [17, 18].

pH value: It is an important factor affecting the degradation of materials in the composting process, depending on the environment, so that the microorganisms involved are active within specific ranges of pH [14, 19, 20]. The measurement of the pH of the composted material every 2 days throughout the experimental period (Figure 3) showed that the pH during the composting process of organic waste with rice husks, coconut coir dust, and small dry leaves as the medium in the compost bin was lower in the initial stage of composting and was favored by a slightly acid pH. This is because the microbial degradation activity of carbohydrate-type organic compounds produces organic acids. After that, the pH tends to increase towards neutral when organic acids are converted to carbon dioxide by the action of microorganisms and ammonia is released from the protein degradation process [5, 7]. The neutral pH of the compost indicated that the compost has matured [14], and the pH has subsequently increased [7]. The result showed that all 3 treatments had pH values in the range of 5.5-8.5, which is in the organic fertilizer standard B.E. 2548 [21].

3.2 Analysis of the macronutrient contents of compost from the household compost bin

At the end of the fermentation process, compost material samples were taken to analyze the physical and chemical properties of the compost material and compared the quality of the fermented product with the organic fertilizer standard (Table 1). All 3 treatments had moisture content, pH level, salinity level (in terms of electrical conductivity), amount of organic matter, organic carbon, carbon/nitrogen ratio, total nitrogen content, total phosphorus content, and total potassium content, which followed the organic fertilizer standard of the Department of Agriculture [21]. Accordingly, these composts can be used as soil amendments.

The results from the chemical analysis of the samples from 3 treatments of rice husks, coconut coir dust, and small dry leaves as composting mediums (Table 1) showed that the treatment with coconut coir dust as the medium had a higher moisture content than the others. Due to coconut coir dust being lightweight, a fiber, and able to absorb and hold water well, this may lead to less drainage and ventilation [22]. The pH

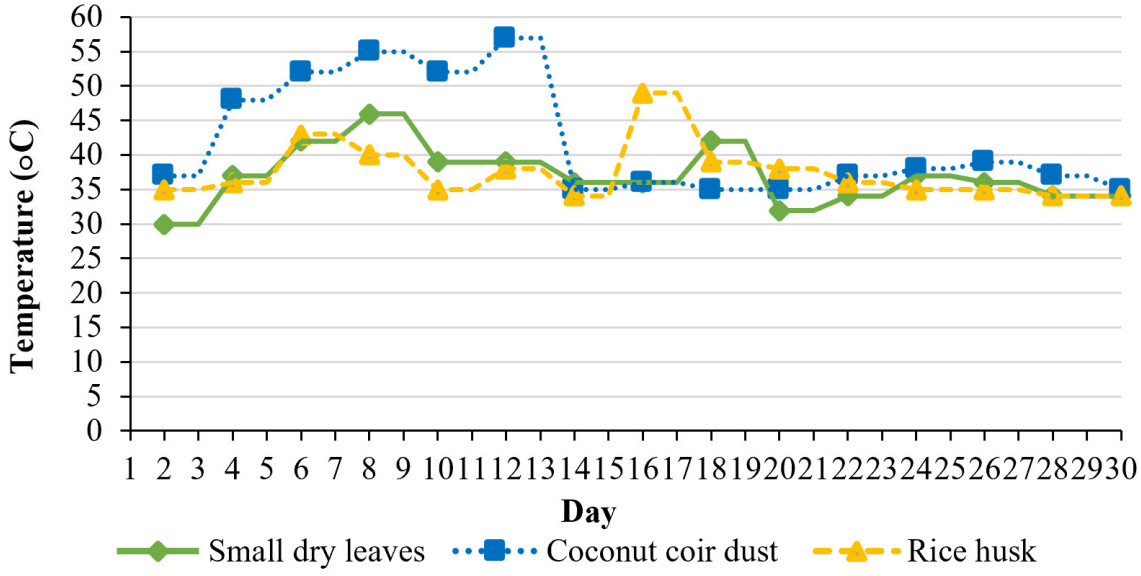

Figure 1: Temperature change during composting in the compost bin.

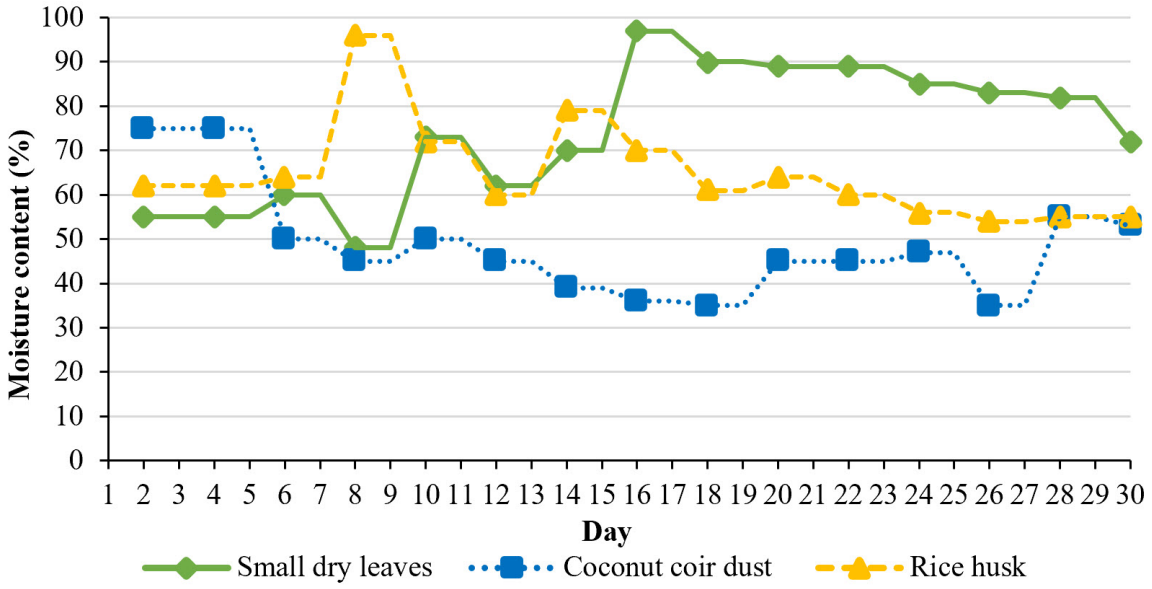

Figure 2: Moisture content change during composting in the compost bin.

affects the activity of microorganisms, thereby affecting the decomposition of organic materials. In general, the decomposition of organic materials at neutral pH (pH = 7) occurs faster in the acidic or overly alkaline range (below 4.5 or above 9.0) [14]. This is because the pH of compost depends on the raw materials used for composting [8]. Coconut coir dust has a pH value of 5.43, and rice husks have a pH value of 5.93 [23]. Thus, it may result in the treatment with coconut coir dust as the medium having a lower pH than other treatments. The electrical conductivity is the value that indicates the salinity or soluble salt in the fertilizer. pH does not directly affect the electrical conductivity, but it may indirectly affect the salt solubility and moisture content of the fertilizer. It can be seen that the treatment with coconut coir dust as the medium had higher electrical conductivity than the treatment with rice husks and small dry leaves as the medium because compost has a low pH level. Moreover, they had a high soluble salt content and high electrical conductivity [24]. Organic carbon is an important component of organic matter and is used to assess the process by which organic matter is degraded by microorganisms. The carbon content of organic matter is important for the composting process because microorganisms decompose organic matter to

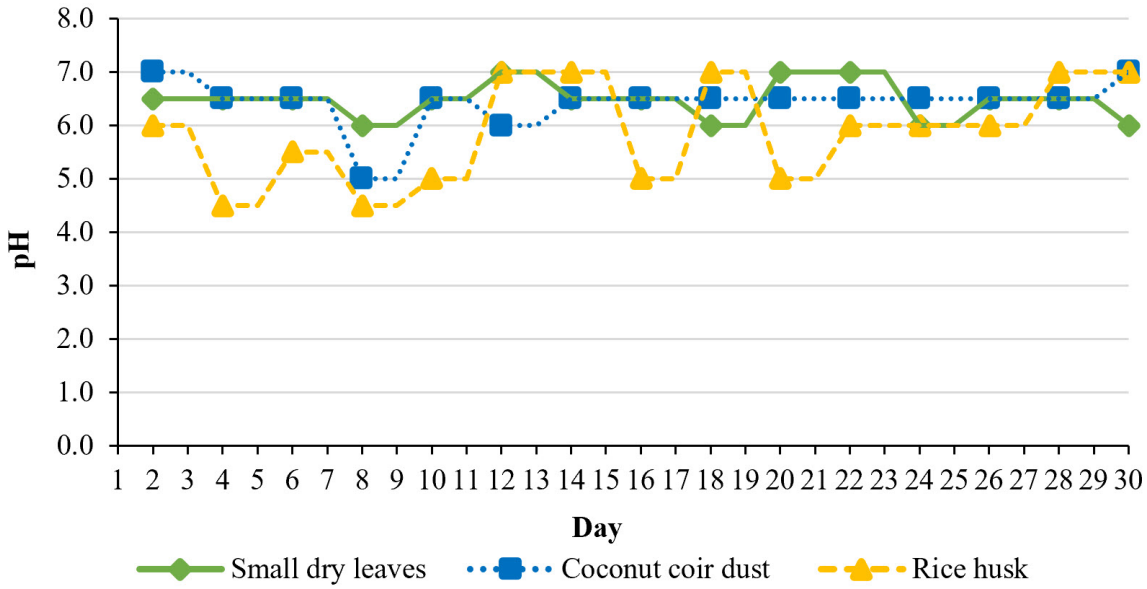

Figure 3: pH level change during composting in the compost bin.

Table 1. The quality of the compost material at the end of composting compared to the organic fertilizer standard

The quality of the compost	Organic material as a composting medium			Criteria1
material	Rice husks	Coconut coir dust	Small dry leaves	
Moisture content	12.95	17.93	12.20	<35%
pH level	7.60	7.36	7.68	5.5-8.5
Electrical conductivity (EC)	0.009	0.015	0.014	<6 dS/m
Organic matter (OM)	49.80	42.35	39.17	>30%
Organic carbon (OC)	28.96	24.62	22.77	-
Total nitrogen content	1.73	2.22	2.33	>1%
Total phosphorus content	0.69	0.74	1.18	>0.5%
Total potassium content	1.10	1.99	1.86	>0.5%
C/N ratio	16.74	11.09	9.77	<20:1

Notation
1/Announcement of the Department of Agriculture: Organic Fertilizer Standard B.E. 2548 [21]

use carbon to create cell components for growth [25]. In addition, organic matter is very important for cultivation as a source of plant nutrients (especially nitrogen). Most plants obtain phosphorus and sulfur from the decay of organic matter. Thus, the amount of organic matter allows for the assessment of soil fertility [20]. From the study, it can be seen that the treatment with small dry leaves as the medium has a large percentage of organic carbon and organic matter, which is lower than other treatments. This may be because microorganisms have a greater decomposition process than other treatments. The compost with rice husks as the medium contains the highest amount of organic matter, which means that this type of compost can affect the growth of the cultivated plants very well. As a result, the quality of cultivation and the productivity of farmers are high. Organic carbon is an important component of organic matter that is used to assess microbial degradation processes occurring in organic matter. The amount of carbon contained in organic matter is important for microorganisms, as they decompose organic matter to use carbon to make cell components for growth [25]. The decomposition of organic matter is caused by microorganisms that use carbon as their energy source and nitrogen as their nitrogen source to build cell structures, so their demand for carbon is greater than that for nitrogen. If excess carbon is excessive, decomposition dwindles when nitrogen is exhausted and some organisms die. The stored nitrogen is used by other organisms to create new cell materials, and more carbon is used in the process. Accordingly, the carbon content is reduced to a more optimal level while nitrogen is recycled [7]. If the compost contains a mixture containing carbon and nitrogen below the optimal value, high nitrogen content results in excessive nitrogen consumption by microorganisms, and nitrogen is lost in the form of ammonia gas. Especially under conditions of high temperature and pH, ammonia gas and foul odor will be produced, and the resulting fertilizer will make the

soil acidic (NH4)2SO4 because each organic material has a different carbon/nitrogen ratio. Therefore, in the production of compost, materials with an appropriate carbon/nitrogen ratio [14, 15] should be used to make compost that is produced from good-quality organic waste and can be used effectively in the future [26].

Nitrogen is a nutrient that microorganisms need in large quantities for their growth because most of the components of the microbial cell are proteins and nucleic acids, of which nitrogen is an important constituent [25]. It can be seen that the treatment with small dry leaves as the medium had a higher percentage of total nitrogen than other treatments. Most of the small dry leaves are Samanea saman, which is a perennial plant with cotyledons and is in the same family as legumes. The leaves have a high nitrogen content due to the presence of the bacteria Bradyrhizobium in the root node, which helps fix nitrogen and is a good source of nitrogen for plants and animals. It is often planted to add nitrogen to the soil or to improve the soil, used to make fertilizer, and made into animal feed. The leaves of Samanea saman contain nitrogen up to 3.25%, which is higher than other leaves that are not legumes [27, 28]. Phosphorus in organic compounds is essential for the fermentation process, as is nitrogen. Phosphorus is the number of nutrients that microorganisms use in the fermentation process, which is used for the growth of microorganisms. The phosphorus content of compost is in the form of P2O5 [25]. It can be seen that the compost with small dry leaves as the medium had a higher percentage of total phosphorus than the other treatments because microorganisms decompose organic matter by using phosphorus as a nutrient to aid growth. The results showed that the compost with coconut coir dust as the medium had the highest percentage of total potassium, which is a lightweight planting material with the ability to hold water, good ventilation, and low nitrogen and phosphorus content. Nonetheless, coconut coir dust has a potassium content that is quite high compared to other waste organic materials [29]. The change in the C/N ratio of compost indicates the degradation effect of organic matter and is an index used to describe the maturity and quality of fermentation products [5].

4. Conclusions

Based on the study and survey of preliminary information on the type, quantity, and management of solid waste, especially organic waste, it was found that at present, most households in the personnel condominium of Yala Rajabhat University disposed of solid waste in the same container without sorting. The type of organic waste in the household each day is food waste, e.g., rice scraps, snack scraps, vegetable scraps, and fruit peels. Most of the residents in the personnel condominium opined that sorting food scraps before throwing them out is not a burden because it is easy to do. They agreed that there were household compost bins available for use in the area of the personnel condominium. Hence, the prototype of the household compost bin was made from a 200-liter HDPE polypropylene plastic tank, placed vertically on a steel stand with stirrers inside the tank. Subsequently, the organic waste or biodegradable waste in the household, e.g., food scraps, vegetable scraps, and fruit scraps, was composted together to make fertilizer with residual organic materials including rice husks, coconut coir dust, and small dry leaves. Then, the Super LDD 1 Microbial Activator of the Land Development Department was added to assess the efficiency of the household compost bin through the aerobic decomposition process. According to the experiments, it was observed that the composted household organic waste in the compost bin for 30 days was soft, crumbly, easily torn, and soil-like smell, and the color of the fermented material was dark brown. However, during the composting process, there is a foul or rotten egg smell in the early stages. At the end of the fermentation process, the compost material samples were taken from the compost bin, and the physical and chemical properties of the compost material were analyzed, and compared the quality of the fermented product with the organic fertilizer standard. All the 3 different fermented materials clearly show the amount of moisture content, pH level, salinity level (in terms of electrical conductivity), amount of organic matter, organic carbon, carbon/nitrogen ratio, total nitrogen content, total phosphorus content, and total potassium content following the Organic Fertilizer Standard B.E. 2548 (2005) of the Department of Agriculture, Thailand. Thereby, this showed that these composts can be used as a soil improvement material. This research presents one of the alternative ways to manage household organic waste that is more environmentally friendly. Likewise, the farmer's cultivation area may contain other agricultural waste that may be beneficial to the crops. Consequently, it is suggestible to study and compare composting with other natural materials in the agricultural area to determine which fermentation methods provide the most effective nutrient content for plants.

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Participatory Management for Sustainable Low-Carbon Community in Highland Community, Thailand

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Abstract

The concept of sustainable development by using participatory management is trendily favored for developing low-carbon communities. This research aimed to investigate participatory management for developing sustainable low-carbon communities, community performances in sustainable low-carbon communities, and contributing factors of these performances. The research area was located at Pa Pae Village, Pa Pae Sub-District, Mae Sa Rieng District, Mae Hong Son Province, Thailand. Data were analyzed from in-depth interviews, focus groups, and document investigations. The results indicated that participatory management consisted of a cycle of three stages, need identification, planning, and implementation, which required community meetings to make discussion and decision. The performances in sustainable low-carbon communities also involved environmentally friendly agriculture, forest restoration, conservation, community health management, community strength, and efficient use of resources. These performances relied on socio-culture of community, community leaders, and encouragement of agency. Therefore, participatory management should include the stage of evaluation. Leadership development in participatory management should be also focused to continue the community performances in sustainable low-carbon communities, along with encouraging active social learning process to achieve the goal of sustainable development.

Keywords: food waste, compost, household compose bin

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1. Introduction

There has been an economic trend towards a low-carbon community, society or city which aims to control the use of natural resources and pollution and involves different strategies under the concept of sustainable development [1]. UK government promotes hundreds of low-carbon community groups to reduce greenhouse gas emissions in response to climate change [2]. The energy policy of Japan also directs to increasing the use of renewable energy up to 22-24 percent in 2030 and reducing greenhouse gas up to 80 percent in 2050 [3]. In addition, China drives programs and projects through provincial and municipal government to create a low-carbon eco-city that involves performance indicators of efficient use of resources, a friendly environment, sustainable economy, and harmonious society [4]. In Thailand, the low-carbon society was included in the national, social, and economic development plan since 2011 which focuses on changing human behavior to reduce greenhouse gas emissions in residential communities, workplaces, business, industry, agriculture, and tourism [5].

The term 'low-carbon community' has been discussed in various perspectives. Liu e et al (2021) describes this term as a community that has low carbon emission and environmentally friendly environment such as green buildings and effective energy management [6]. In contrast, Heiskanen et al (2010) argued that a low-carbon community is a form of cooperation and collaboration to strengthen behavior change for reducing carbon emissions in communities which depends upon the appropriate mechanisms and contexts of each community [7]. Low-carbon community also associates with three stages of low-carbon development; low-carbon economy or primary stage (achieve low-carbon industry, low-carbon tourism), low-carbon society or developmental stage (achieve low-carbon community, low-carbon life, and low-carbon city), and low-carbon world or maturity stage (achieve low-carbon over the world in economy, politics, culture, and life), respectively [8]. However, the literature indicates that communities have the capacity to create low-carbon activities and drive individual behav-

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ior change toward the environment [9]. For example, indigenous communities in Uganda adapt their knowledge in response to climate change especially in agricultural practices (planting, weeding and harvesting) [10]. In Thailand, Sampaya Community, Cha-Am District, Phetchaburi Province, determines four low-carbon strategies which consist of reducing carbon emissions from activities of production and consumption, educating community members about low-carbon community, building participation with community members and agencies, and developing low-carbon transportation [11].

In addition, participatory management has been implemented as a tool or strategy for developing low-carbon communities since this approach focuses on the process that builds participation in practices to achieve the goal of organization or community [12]. Such process is a series of activities and actions engaging with sharing decision-making, implementation, benefits, and evaluation [13]. Therefore, participatory management provides several advantages; stimulating a sense of belonging to common missions, improving decisions and actions, facilitating collective learning, increasing opportunities for success, and strengthening community [14]. For example, Bangladesh people in the southwestern region participated in reforestation to increase carbon stocks along roads and highways [15]. The carbon market developed by Vietnamese people also contributes to reducing greenhouse gas emissions by nine percent [16]. Farmers at the learning center at Klong Noi Community, Mueang District, Surat Thani Province, Thailand achieve the practices of a low-carbon agricultural community after farmer leaders stimulate group activities of non-chemical agricultural practices. They also obtain benefits from non-chemical agricultural practices, such as reducing production costs and encouragement of sub-district administrative organizations and departments of agriculture to be obtained encouragement in need [17]. However, some scholars mention about barriers of participatory approach; for example, inadequate community skills, limited time, and insufficient conversation [18].

This research aimed to investigate participatory management for developing sustainable low-carbon communities, community performances in sustainable low-carbon communities implementing participatory management, and contributing factors of these performances. Participatory management was defined as the process that built participation in sustainable low-carbon communities and sustainable low-carbon communities referred to the participation of community members to perform activities reducing carbon emissions in response to the concept of sustainable development. The research was conducted in the area of Pa Pae Village, Pa Pae Sub-district, Mae Sa Rieng District, Mae Hong Son Province where people had experience in participatory management for developing sustainable low-carbon communities and the performances of sustainable low-carbon communities, certified by the Royal Project and Highland Research and Development Institute and Mahidol University.

2. Methods

2.1 Area of Study

The area of study selected for this research was limited to a small highland village in the North of Thailand which is located at Pa Pae Village, Pa Pae Sub-district, Mae Sa Rieng District, Mae Hong Son Province. The total population of this village was 405 residents in 93 households and most villagers were Laue, an ethnic group. This village was surrounded by mountains and trees which was related to livelihoods depending upon natural resources, especially agricultural practices.

2.2 Scope of Study

The investigation in this study focused on the issues about sustainable low-carbon communities:1) how leaders conduct participatory management for developing sustainable low-carbon communities; 2) what community performances in sustainable low-carbon communities implementing participatory management are; and 3) what factors contributed to such community performances and how they were.

2.3 Data Collection

Permission to conduct this research were granted by the village leader at Pa Pae Village. After that, three qualitative methods were used to collect data, i.e., document investigation, focus group, and in-depth interview. Document investigation included archival materials from participants such as reports, memos, and pictures. Researcher purposively selected twenty participants, who were able to provided information according to the objectives of this study, for in-depth interview and focus groups. Entire participants were able to provide information voluntarily and stop providing information whenever they want. They were divided into three groups—leaders, villagers, and agencies. Leaders consisted of the village leader and the community committee at Pa Pae Village who had experience in participatory management for developing sustainable low-carbon communities. Villagers were community members who lived in Pa Pae Village and engaged in the performances of sustainable low-carbon communities. Agencies included representatives of government officials from Mahidol University and the Royal Project at Pa Pae District who encouraged leaders to develop sustainable low-carbon communities. In in-depth interviews, researchers used semi-structured interview forms which focused on different sets of questions for each group of participants.

Leaders were asked about how to conduct participatory management for developing sustainable low-carbon communities, what community performances in sustainable low-carbon communities and what suggestions for improving community performances are, and what and how contributing factors are involved in such community performances. Villagers were asked about what and why they engaged in sustainable low-carbon communities, and what suggestions for improving the performances of sustainable low-carbon communities. Agencies were asked about how to encourage sustainable community development at Pa Pae Village. In addition, researchers organized focus group discussions to gain information according to the objective of this research. Five leaders were invited to discuss about participatory management for developing sustainable low-carbon communities, community performances in sustainable low-carbon communities, suggestions for improving such community performances, and contributing factors of such community performances, and five villagers were invited to discuss about their engagement in sustainable low-carbon communities and suggestions for further performances of sustainable low-carbon communities.

2.4 Data Analysis

All data collected from in-depth interview and focus group, along with document investigation, were recorded, transcribed, and analyzed, respectively. Data analysis consists of coding, constant comparative methods, and memo-writing which were important procedures for the accuracy and completion of descriptive data. Coding was the stage of categorizing segments of data or naming and organizing data. During coding, constant comparative methods were occurred to distinguish the similarities and differences between data and categories. At the same time, memo writing or simple note taking were continuously developed and improved. In other words, memo writing provided a draft of description and directed further coding and constant comparative methods until the description was completed.

3. Results

3.1 Participatory Management

Participatory management for developing sustainable low-carbon communities was embedded in the process of community development. It consisted of a cycle of three stages (see figure 1): need identification, planning, and implementation. This cycle required community meetings where Pa Pae villagers were able to make decisions from sharing and discussing information, need, problems, ideas, and opinions about community performances of sustainable low-carbon communities. Normally, the community committee at Pa Pae Village organized and led the community meetings for managing the development of the village on regular basis every month. The details of each stage were described below.

3.1.1 Need Identification

This stage focused on identifying the advantage and need to conduct sustainable low-carbon development before making decision in the next step. After the community committee and villagers obtained information about sustainable low-carbon communities from the Royal Project Development Center at Mae Sa Rieng District, Mae Hong Song Province, they discussed about sustainable low-carbon communities in the community meeting and agreed that carbon emission for sustaining community economy was inevitable. Moreover, the community committee and villagers accepted that they would obtain several advantages from engaging with sustainable low-carbon communities; living in magnificent environment, conserving forests for further use maintaining sufficient livelihoods, and enhancing quality of life.

3.1.2 Planning

Since the community committee and villagers realized the need to conduct sustainable low-carbon communities, relevant information was gathered to identify what and how to conduct. The Royal Project Development Center at Mae Sa Rieng District, Mae Hong Son Province also provided them information and checklist of actions before they discussed about action plan for sustainable low-carbon communities, including environmentally friendly agriculture, forest conservation, environmental health, community strength, and natural resource use. This action plan was imbued with the master plan of village development. The community committee and villagers also assigned the tasks of each team in the action plan to demonstrate their accountability toward the environment.

3.1.3 Implementation

This stage focused on the implementation or performances as specified in the previous stage for achieving sustainable low-carbon communities. During implementation, the community committee and the villagers were able to share their problems, obstacles, and results in the community meeting. They made decisions to continue the activities that derived advantageous results. In contrast, disadvantageous activities were changed to improve the performances of sustainable low-carbon communities. They also continued the next cycle to review their decisions, revise the action plan, and adjust implementation.

3.2 Community Performances in Sustainable low-Carbon Communities

The performances of leaders and villagers at Pa Pae Village complied with the indicators of sustainable low-carbon communities developed by the Highland Research and Development Institute and Mahidol University. These performances were divided into

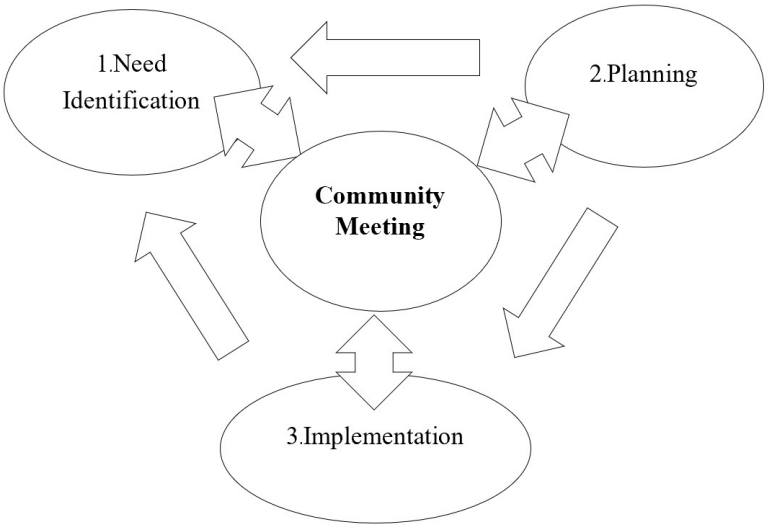

Figure 1: The process of participatory management

five categories as demonstrated in Table 1. Each category also required regular actions and improvements to create sustainable low- carbon communities at Pa Pae Village continuously.

3.3 Contributing Factors to Community Performances

3.3.1 Socio-Culture in Community

In general, Pa Pae villagers had strong culture of social cooperation and sufficient livelihoods. They respected the leaders of the village and cooperated in social events of the village and community members. Their livelihoods also depended upon natural resources in forest areas around the village, especially agricultural practices and collecting forest products, which promoted their awareness to protect natural resources and the environment.

3.3.2 Community Leaders

The village leader and the community committee at Pa Pae Village agreed to lead community to sustainable development since they realized the importance of natural resource and environment in livelihoods. Then, they focused on explaining to villagers in the community meeting and daily talk about the advantages of driving to achieve sustainable low-carbon communities; for example, living in magnificent environment, conserving forests for further use, maintaining sufficient livelihoods, and enhancing the quality of life. Consequently, most villagers participated in the activities of sustainable low-carbon communities.

3.3.3 Agency Support

The Royal Project Development Center at Mae Sa Rieng District, Mae Hong Son Province encouraged Pa Pae Village to perform activities of sustainable low-carbon. They acted as mentor to guide and advise the community leaders how to develop and achieve sustainable low-carbon. They also educated leaders and villagers about sustainable low-carbon communities at Pa Pae Village which helped promote participation in the program. In addition, local administrative encouraged related activities of sustainable low-carbon communities, especially community cleaning and forest conservation.

4. Discussion

The findings of this research highlighted the process of participatory management for developing performances of sustainable low-carbon communities which included need identification, planning, and implementation. This process required the regular meeting, e.g., a community meeting, where functioned as a common platform for communication and discussion leading people to make decisions and commitment toward the mission of carbon emissions [12]. However, building participation should include the stage of evaluation which emphasized the achievement of sustainable low-carbon communities and the benefits toward community members and environment [13]. In addition, the levels of participation should be considered in participatory management, information provision (one-way communication), consultation (two-way communication), active involvement (resources, time, tools, and costs), and social learning (intensive sharing idea and knowledge to convince other people) [19]. In the case of Pa Pae Village, the stage of need identification implied participation at the level of information provision from agency about what sustainable low-carbon communities are. Two-way communication was also conducted between community leaders and community members directing to share ideas and responsibilities for implementing sustainable low-carbon communities which indicated participation at the level of

Table 1. The community performances and suggestions for sustainable low-carbon community at Pa Pae Village, Mae Hong Son Province

No.	Categories	Performances	Suggestions
1	Environmentally Friendly Agriculture	- Avoid using chemical substances and pesticides in farmland by focusing on organic farming and good agricultural practices (GAP); however, ten farmers and twenty-four farmers are certified respectively. - Focus on soil restoration by using lime and organic fertilizer (manure and compost) including crop rotation, and planting vetiver. - Use sprinkles and traditional methods to save water (rainwater, watering can, and stagnant water in filed plot) in agricultural practices, including releasing less water into rice fields.	- Should encourage entire farmers to request certification of organic farming or GAP. - Should promote water management plans to control water use and maintain water quality. - Should monitor water and soil quality regularly.
2	Forest Restoration and	- Collect data about forest area boundary of community, agriculture areas, tree position, fire brake line, and forest fire areas which help plan forest restoration and conservation. - Determine community regulations for protecting forests such as banning felling trees and using forest products. - Conduct related activities such as breeding plants, planting trees and local plants, building firebreaks, and building weirs to increase humidity in the forest. - Report and monitor activities of forest restoration and conservation.	- Should post forest regulations to community members in public space and continue activities of forest conservation to stimulate conservation awareness. - Should encourage propagation and cultivation of local plants for forest and biodiversity conservation.
3	Community	- Promote neat, tidy and clean houses supported by local administrative organization, public health volunteers and the Royal Project at Pa Pae District which led to obtaining the clean community award of the year 2021 from the local administrative organization. - Encourage waste sorting in households to organic waste, recycle waste, and hazardous waste. For wastewater drainage, connect the wastewater pipe from households to layer filters of rock, sand, and soil in a circular cement pond before releasing water to the ground. - Determine the area for a community waste pit and regulations for using the community waste pit. - Maintain quality of drinking water sources by cleaning water tanks and monitoring water quality in the water tanks. - Educate community members about using water filter and boiling water before drinking.	- Should record the type and amount of waste in households and communities for developing a waste management plan. - Should promote waste reduction such as using cloth bags instead of plastic bags, and reusing waste. - Should improve community waste management such as preventing rubbish scattering from animals in the community waste pit, and building participation with community members.
4	Community Strength in Response to Changes	- Focus on planning process for community development: problem and need identification, SWOT analysis, and solution proposal. - Integrate the philosophy of sufficiency economy into community activities; for example, saving, cooperative management, promoting occupation and income, preventing youth from drug addiction, and conducting public benefit activities. - Provide handicraft learning center of Lava ethnics.	- Should promote learning process to empower leaders and community members for adapting to changes.

Table 1. The community performances and suggestions for sustainable low-carbon community at Pa Pae Village, Mae Hong Son Province (Con.)

No.	Categories	Performances	Suggestions
5	Resource	- Educate energy saving in the household; for example, carpooling and using firewood. - Reduce forest exploitation. - Promote planting economic trees after felling trees.	- Should save economic forest products for sustainable livelihoods.

consultation and active involvement, especially individual resources and times. However, Pa Pae Village should improve participation at the level of social level to empower intensive communication and education.

This research also indicated that the community leader is a contributing factor to community performances in sustainable low-carbon communities implementing participatory management. Therefore, leadership development is essential to achieve sustainable low-carbon communities. In this sense, the community leaders should have the competency of self-management (awareness of leadership, learning ability, and conflict management), social skills (building and maintaining relationships, building effective teamwork, and communicating with people), and facilitation skills (creative thinking, strategic thinking, managerial skill, and coping with change) [20]. Kirk and Shutte (2004) [21] propose triangle framework of community leadership development which are composed of connective leadership (building common goal and team work), leading change through dialogue (promoting collective learning and participatory action), and collective empowerment (developing social relationship which leads to realize on community role). However, how to develop community leadership for participatory management is required further research to achieve sustainable low-carbon communities, especially in a period of rapid change in the community.

5. Conclusion

Participatory management for developing sustainable low-carbon communities was embedded in community development and involved a cycle of need identification, planning, and implementation. This cycle was driven by regular meetings where people were able to make discussions and decisions together. The community performances of sustainable low-carbon communities derived according to participatory management included environmentally friendly agriculture, forest restoration and conservation, community health management, community strength, and resource-saving. The contributing factors of these performances consisted of socio-culture in the community, leaders, and agency support. However, community leaders should emphasize the stage of evaluation in participatory management to increase the effectiveness of developing sustainable low-carbon communities. The government should also focus on leadership development to continue the community performance in sustainable low-carbon communities and should encourage an active social learning process to fulfill participatory management for achieving the goal of sustainable development. In addition, a study about developing leadership in participatory management for sustainable low-carbon communities should be conducted.

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Promoting EFL Thai Undergraduates' Reading Comprehension and Reading Motivation through Extensive Reading

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Abstract

The study examined the improvement of EFL Thai undergraduates' reading comprehension through extensive reading and investigated the enhancement of EFL Thai undergraduate students' motivation towards extensive reading in English. One hundred and nine Thai non-English major undergraduates participated in the study over ten weeks. Quantitative data were collected through the pre- and post-reading comprehension tests and pre-and post-Motivation for Reading questionnaires. Semi-structured interviews were conducted to get qualitative data. The results revealed that there was a significant enhancement in both EFL Thai undergraduates' reading comprehension and reading motivation after implementing extensive reading. The findings suggested that extensive reading is an effective method for EFL students in improving their reading abilities, particularly their reading comprehension skills. Therefore, extensive reading should be promoted in English classrooms.

Keywords: Extensive Reading, Reading comprehension, Reading motivation

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1. Introduction

Regarding the importance of language used for communication, the English language has been taught in schools and universities throughout Thailand. Reading skill is considered the most crucial skill among others as it is an instrument to acquire knowledge. However, ineffective reading methods have been implemented in the English classroom leading to a monotonous atmosphere and discouraging students to read. Extensive reading (ER) has been widely used and implemented in the teaching of EFL. Nuttall [1] believes that one of the best ways to enhance English language skills is to read extensively. Several research studies have suggested the benefits of ER on learners' English reading abilities and reading motivation. ER can improve reading comprehension, reading fluency, vocabulary acquisition, and better writing skills [2, 3, 4]. Apart from developing students' English abilities, ER promotes students' motivation to keep reading and to create an enjoyable atmosphere in learning second and foreign languages [5, 6].

It can be discovered that not many higher education institutions in Thailand encourage students to develop undergraduates' reading comprehension through ER, but through the grammar-translation method even though ER has been a popular approach to promote students' English language skills development among ESL and EFL teachers [7, 8, 9]. Moreover, a small number of studies have been conducted on ER in Thai teaching and learning context and most studies did not concentrate on a large group of participants [10]. Furthermore, only a few research studies of ER have investigated students' reading motivation [11]. Although the studies conducted on ER in Thailand in tertiary education revealed that ER can be beneficial in promoting reading comprehension, students still perceived no practical value that ER can lead to their success in study or future careers, and less than half of students wish to continue reading extensively [8]. More importantly, Thai universities have not yet integrated ER with the students, but only intensive English [9]. Therefore, it was interesting to make use of ER with EFL Thai undergraduates to examine their reading comprehension and explore their reading motivation and whether ER could be successfully done with EFL Thai undergraduates who were novice readers. With the intention of filling the gap, the present research was conducted and its objectives were formulated to examine the improvement of reading comprehension of EFL Thai undergraduates by ER and to investigate the enhancement of the motivation of EFL Thai undergraduates towards ER in English.

2. Literature Review

2.1 Extensive Reading

Extensive reading (ER) is "reading in quantity in order to gain a general understanding of what is read, to develop good reading habits, to build knowledge of

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vocabulary and structure, and to encourage a liking for reading" [12]. ER is effective in acquiring foreign languages when learners choose the texts that meet their level of difficulty. Day and Bamford [13] determined the top ten successful characteristics of the ER program. They include easy materials, various reading materials with a wide range of topics, assurance of students' choice in selecting books, maximum reading, speedy reading, pleasure of reading, individual and silent reading, reading in its own rewards, reading under teachers' orientation, and guidance teachers' role model. The aim of ER is to read for pleasure in which students enjoy reading the texts they choose by themselves to fulfill their personal enjoyment outside the classroom. Students will be enriched with their vocabulary and knowledge naturally from the context. In order to engage students in further reading and boost students' reading motivation, followed-up activities should be provided after reading [14]. ER helps students improve their fluency, reading speed, and reading comprehension [15]. It is also believed that students can develop good reading habits, and improve positive motivations towards ER [16].

2.2 Extensive Reading and Reading Comprehension

Reading comprehension is "the construction of meaning of a written or spoken communication through a reciprocal, holistic interchange of ideas between the interpreter and the message in a particular communication context" [17]. The main purpose of reading is to comprehend the entire text rather than to examine every word and sentence. ER helps students improve their reading comprehension by reading quickly and enjoyably with adequate comprehension without a dictionary [18]. It is believed that learners can develop good reading habits, build up vocabulary knowledge, and improve their comprehension through ER which should be continued over a period of time. A number of studies have been conducted on ER in reading comprehension in EFL teaching and learning contexts. Nguyen [19], in line with Nutalak [4], found that the experimental group could read and understand the text better, and could recognize the meaning of the vocabulary than the control group after implementing ER over eight weeks. In addition, Endris [20] supported that the intervention group got higher scores on the reading comprehension test after implementing ER for 12 weeks even though there was no significant difference between the intervention and the control group during the first six weeks. Therefore, it can be suggested that students' reading comprehension can be promoted through ER.

2.3 Extensive Reading and Reading Motivation

Motivation has a big influence on the foreign language learning process and it plays an important role since it provides the initial push to success [21]. When students have reading motivation, they will engage more in ER because of their positive attitudes toward reading. To successfully develop a reading motivation model for ESL and EFL students, an effective ER program requires four major components [22]. The first component is materials. To lead to an increase in motivation, reading materials must be interesting and attractive. Interest should be a key factor in the selection of reading materials since interest greatly influences reading motivation [23]. Importantly, the level of the books must meet students' reading competence. The second component is reading ability in L2. Students who have low reading ability tend to have low reading motivation since they are likely to have a low expectation of success. The third component is attitudes toward reading in L2. Teachers, classmates, and activities have a great impact on students' attitudes toward reading in L2. Students who have more engagement in reading activities tend to have higher reading motivation [24]. Moreover, positive environments, such as a comfortable library, and easiness of accessing and searching reading materials, can increase students' reading motivation. The last component is the socio-cultural environment. Students who are from the family that actively pursued literacy activities in foreign languages tend to value reading more than students whose families did not [25]. Nevertheless, it is advised that reading materials and attitudes towards reading in L2 have stronger effects than the other two components [22]. All in all, extensive reading, reading motivation, and reading abilities are related to each other. When ER is well-established, students are motivated to read.

3. Methodology

3.1 Participants

The participants were limited to 109 undergraduate students at Nakhon Pathom Rajabhat University. Seventy-seven participants studied Mathematics as a major concentration and the rest of them were from Primary Education. Eighty participants were female. The majority of them were 19 years old. They enrolled in 1500011 Fundamental English II during semester 2 of the academic year 2021 in the researcher's sections. Before enrolling in 1500011, they studied 1500010 Fundamental English I in the first semester of the academic year 2021. The majority of participants' English language proficiency was A2 CEFR level, which was measured by a standardized English test that is aligned to the CEFR and is backed by Qualifications and Assessments International (QAI) in the UK. In order to achieve the research objectives, the researcher selected the samples by using intact sampling, non-probability sampling, which were four groups of students who enrolled in those four researcher's sections.

3.2 Research Instruments

The instruments were pre- and post-reading comprehension tests consisting of six passages selected

from the textbooks published by reputable publishers which clearly stated that the contents and the passages were appropriate for A2 CEFR level. The reading comprehension test had 45 questions with each question worth one point. The pre- and post-MRQ on the 5 Likert's scale consisting of 26 statements were adapted from the Motivations for Reading Questionnaire (MRQ) constructed by Wigfield and Guthrie [26] and the Motivation to Read Profile (MRP) constructed by Gambrell, Palmer, Codling, Mazzoni [27] to be suitable for EFL students. Moreover, 5 opened-ended questions for semi-structured interviews were created by the researcher to collect more details and opinions, and affirm the results of motivation towards ER. The reliability and validity of the research instruments were validated by three experts in the field of TEFL, and they were piloted with a group of students who shared the same characteristics.

3.3 Research Procedures

The researcher informed the participants about the purposes, the procedures of ER program, and ethical issues. They were given consent forms and were informed that they could withdraw at any time without negative consequences. Then, a pre-reading comprehension test and a pre-MRQ were given. During the study, students formed a group of four based on their choice. Then, they were given a variety of online graded readers with various genres and topics on Xreading. They could select what they wanted to read by themselves, and were requested to read at least 5 graded readers from level 6 – 9, (A2 – B1 CEFR level) in their leisure time. After finishing each graded reader, they took an online quick quiz and recorded what they read on a reading record individually to recheck their comprehension. Plus, a 25-minute group discussion was allocated to talk about the summary, their favorite character, the most interesting thing, and difficulties and challenges to gauge their reading comprehension. At the final stage, students were asked to take a post-reading comprehension test and a post-MRQ. Finally, 12 students were randomly selected for the semi-structured interviews related to their motivation toward ER. The interview was conducted in Thai in order for students to feel comfortable, to give clear explanations, and not to have any language barrier.

3.4 Data Analysis

The SPSS was used to analyze data obtained from pre- and post-reading comprehension tests by using t-test for dependent samples in order to get descriptive statistics, as well as the pre- and post-MRQ. Moreover, data obtained from the open-ended questions from the semi-structured interview were transcribed and analyzed by using content analysis, and were summed up using a grouping technique.

4. Results and Discussion

4.1 Results from Pre- and Post-Reading Comprehension Test

Table 1 shows that the mean score of the pre-reading comprehension test was 20.64 (SD = 7.968). After implementing ER, the mean score of the post-reading comprehension test was 31.55 (SD = 7.045). The mean score of the post-reading comprehension test was higher than the mean score of the pre-reading comprehension test, and the significant difference was found at the .05 level (t = 18.641, p = 0.000). The result indicated that EFL Thai undergraduates' reading comprehension has increased significantly. It can be suggested that ER helped EFL Thai undergraduates promote their reading comprehension.

The findings of the study were correlated with the results of previous studies which found that Thai and EFL students' reading comprehension can be enhanced through ER [9, 10, 15, 20]. One of the possible reasons that ER could help students improve their reading comprehension was because students could select the graded readers they were interested in by themselves [13, 20]. Providing students with a wide variety of reading materials is the foundation of a successful reading program [28]. Another possible reason was group work activities. They are useful components of language practice activities that allow students to enjoy learning languages with their peers [29]. To do ER effectively in order to improve students' reading comprehension, engaging in a group discussion with their peers and teacher was necessary when performing ER tasks since it helped students verify their understanding [11, 30]. Self-logs were also important to promote students' reading comprehension. Although reading logs was a bit tiring due to a lot of assignments from other courses, students agreed that self-logs also forced students to read regularly [31]. From the interview questions, most students agreed that reading for pleasure is a great way to improve their English language proficiency, specifically in reading comprehension skills.

4.2 Results from Pre- and Post-Motivation for Reading Questionnaire

4.2.1 The Overall Motivation Towards Extensive Reading

Table 2 revealed that the mean score of overall reading motivation before implementing ER was 3.25 (SD = 0.510) while the mean score after implementing ER was higher, accounting for 3.44 (SD = 0.444). The mean score of pre- and post-reading motivation towards ER was significantly different at the .05 level (t = 2.972, p = 0.004). Therefore, the results of paired t-test indicated that EFL Thai undergraduates' overall reading motivation after implementing ER was higher. It can be concluded that EFL Thai undergraduates' overall motivation towards ER was enhanced after the implementation.

Table 1. The overall mean, standard deviation, and mean differences of EFL Thai undergraduates' reading comprehension test before and after implementing ER

Reading Test	Students (N)	Pre-test		Post-test		Mean diff.	SD	t-value	p
		Mean	SD	Mean	SD				
Reading Comprehension Test	109	20.64	7.968	31.55	7.045	10.908	6.109	18.641	.000*

*Significant at the .05 level (p <0.05)

Table 2. The overall mean, standard deviation, and mean differences of EFL Thai undergraduates' reading motivation before and after implementing ER

Motivation for Reading Questionnaire	Students (N)	Before Implementing ER		After Implementing ER		Mean diff.	SD	t-value	p
		Mean	SD	Mean	SD				
Motivation towards Extensive Reading	109	3.25	0.510	3.44	0.444	0.19	0.670	2.972	.004*

*Significant at the .05 level (p <0.05)

4.2.2 Each Aspect of Reading Motivation

Apart from the overall motivation towards ER, three aspects of reading motivation were also administered and analyzed quantitively.

Table 3 revealed that the post-MRQ mean score was significantly higher than the pre-MRQ mean score in two aspects of reading motivation – Competence and Reading Efficacy, and Achievement Values and Goals. Regarding Competence and Reading Efficacy, the mean score from pre- and post-MRQ were 2.89 and 3.12, respectively, which the significant difference was found at .05 level (t = 2.788, p = 0.006). Another aspect of reading motivation which the significant difference was found at .05 level (t = 3.429, p = 0.001) was Achievement Values and Goals which the mean score from pre- and post-MRQ were 3.59 and 3.81, respectively. In terms of Social Aspect of Reading, the mean scores from pre- and post- MRQ were 3.26 and 3.39, respectively. Unlike other aspects of reading motivation, the significant difference was not found at .05 level (t = 1.671, p = 0.098). Thus, it can be concluded that ER had a large effect on students' reading motivation of Competence and Reading Efficacy, and Achievement Values and Goals.

The findings of the study were correlated with the results of previous studies. Extrinsic academic compliance, extrinsic test compliance, and intrinsic motivation were the first three highest that helped drive students to read [30]. Uraiman [14] and Anh [32] advised that the importance of reading, extrinsic utility value of reading, intrinsic value of reading, and reading efficacy could be influenced by ER.

Competence and Reading Efficacy increases when students choose the graded readers by themselves and monitor their own progress since challenges arise [33]. It was supported that students' motivation tended to increase when students read challenging books even though the books' level was a bit further than their language competence [34]. Quizzes and reading logs or book reports are the most common forms of monitoring or checking student reading. When students committed to goals, they felt challenged to attain goals leading to forming a virtuous cycle of reading and increasing reading motivation [13]. From the interviews, students agreed that they wanted to select the books by themselves and it led to the willingness to engage with complex reading materials. Plus, a wide variety of reading materials helped increase their motivation toward ER since they had more than one interest.

In terms of Achievement Values and Goals, curiosity has a great influence on driving students to read. The more reading materials attract students' curiosity, the more motivation rapidly increases [35]. In addition, the compliments and positive feedback from teachers and friends encouraged and motivated them to perform well in ER. Reading recognition is one of the main reasons that foster students to read more and even better since they will feel proud when they receive recognition from teachers, friends, and parents [26, 36]. Regarding the interview results, students agreed that teachers and classmates had a big influence on who got them interested and excited about reading English-graded readers.

Social Aspect of Reading emerged as the weakest component of reading motivation of ER among the three dimensions. It was suggested that the influence of peers on students' reading motivation weakens in the late teens, and students perceived reading not as a social activity, but more individualized [37]. Students probably don't prefer to read as their social activity. They read because they are interested in the topic or enjoy reading, not because they want to spend time reading with peers and family or to connect with their groups [38]. However, although the enjoyment of working with peers and teachers can improve students' reading comprehension, it was not sufficient to increase their social aspect of reading motivation [11, 30]. To promote this, cooperative group work should be added more sufficiently so that students have more chances to discuss and share their ideas with their peers. Moreover, reading compliance was relatively low since students have to read because they are assigned to do the assignment. In this study, students did ER voluntarily since students made their own decision to participate in ER and they acknowledged that it was not a requirement and did not have any effect

Table 3. The mean, standard deviation, and mean differences of EFL Thai undergraduates' reading motivation of each aspect of reading motivation before and after implementing ER

Aspect of Reading Motivation	Before Implementing ER		After Implementing ER		t-value	p
	Mean	SD	Mean	SD		
Competence and Reading Efficacy	2.89	0.604	3.12	0.587	2.788	0.006*
Achievement Values and Goals	3.59	0.597	3.81	0.549	3.429	0.001*
Social Aspect of Reading	3.26	0.586	3.39	0.557	1.671	0.098

on any subjects they were studying. Therefore, they were committed to reading the graded readers on the specified amount and completing them by the specified deadline.

5. Conclusion and Recommendation

This study aimed to examine the improvement of reading comprehension of EFL Thai undergraduates by implementing ER, and to investigate the motivation of EFL Thai undergraduates toward ER. The results obtained from the pre- and post-reading comprehension tests revealed that ER affected the students' reading comprehension positively. Moreover, the results from the pre- and post-MRQ showed the students' positive effects toward ER. Achievement values and goals reading, and competence and reading efficacy were the main reading aspects that were motivated by ER.

The researcher tried to set an appropriate ER program according to Day Bamford [22], including a number of books, timelines, and activities, for EFL Thai undergraduates, who were novice readers, to improve students' reading comprehension and enhance their motivation toward ER. Firstly, students should select books by themselves as interests greatly influence motivation. Secondly, the book levels should not be too low or too high, compared to students' English language proficiency. Thirdly, tasks should be assigned to students in order to follow up on their reading progress. To do this, students are able to recheck their comprehension and develop their comprehension as well. Recording their reading activities on self-logs is another effective way that helps students develop their comprehension and can be used as a primary instrument. Lastly, teachers should provide students with good reading environments. Specifically, they should be encouraged to engage in reading activities with their peers, and have a teacher as a facilitator. Group work activities help students verify their understanding and had a great time having a group discussion. However, although group discussion can help students improve their comprehension, it is suggested that other cooperative group activities should be added to enhance their motivation toward ER. Moreover, group activities should be done more often since five-time group discussions per semester may not be sufficient enough to enhance their reading motivation. More importantly, although the findings revealed the positive effects on EFL Thai undergraduates' reading comprehension and reading motivation, it is recommended that the study should be done in the long term or at least two semesters. This is to gradually investigate the progress and affirm the outcomes of ER whether or not the results are comparable to the findings of the current study. Moreover, researchers should conduct ER which has both experimental and control groups so that the results can be affirmed that ER can help students enhance their reading comprehension and reading motivation.

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Exploring Ergonomic Risk Factors and Discomfort Levels in Work-from-Home Settings: A Study during the COVID-19 Pandemic

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Abstract

This study examines the impact of working from home on the ergonomic risk factors and discomfort experienced by workers during the COVID-19 pandemic. Despite the many benefits of working from home, such as increased productivity and flexible working hours, it also presents numerous ergonomic threats, including suboptimal working postures, poor workstation design, uncontrolled working hours, and poor indoor environmental quality. The study aims to identify the risk factors for discomfort among workers who work from home during the COVID-19 pandemic by using an ergonomic assessment tool. The study used an anonymous online questionnaire in Thai, posted on social media platforms, and had a sample size of 303 Thai participants aged 20 years and above, working from home, and using computer for work. Data were obtained through a three-section questionnaire that collected demographic information, workstation assessment, and discomfort scale. The results showed that there is a significant relationship between ergonomic factors and discomfort in the neck, lower back, and legs such as chair, workstation, and breaks. The study concludes that ergonomic assessment tools are essential in identifying potential ergonomic risks and improving the health and safety of workers. Such tools can be tailored to specific industries, job types, or work environments, making them more useful and applicable for different workplaces. This study's findings will help occupational health professionals and policymakers develop and implement effective ergonomic interventions to mitigate ergonomic risks and prevent work-related musculoskeletal disorders (MSDs) among workers who work from home during the pandemic.

Keywords: COVID-19, Work from home, Ergonomics, Workstation, Discomfort

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1. Introduction

The COVID-19 pandemic has drastically altered work patterns, leading to a shift from office-based work to working from home to minimize the risk of infection [1, 2, 3, 4, 5]. While this approach provides benefits such as flexible working hours and increased productivity, it has also posed a significant ergonomic threat due to the lack of proper workstation design, suboptimal working postures, and uncontrolled working hours.

Many people work with awkward postures while using portable laptops in places such as the floor, bed, couch, or chair without proper support, leading to musculoskeletal disorders [6, 7]. The most commonly used workspaces are the living room and bedroom, which often lack furniture designed for prolonged work hours [8]. Furniture commonly found in these rooms, such as chairs, couches, beds, and coffee tables, are not typically designed for prolonged work hours[9].

Although the lockdown campaign has effectively decreased the incidence of COVID-19 cases, it has also presented a new challenge to workers, especially in terms of ergonomic problems [2, 10]. The pros and cons of working from home from the perspective of occupational health and safety have not been thoroughly studied[11]. The limited space and furniture in a home environment can contribute to work-related musculoskeletal disorders (MSDs), compromising workers' health and well-being in the long term.

An ergonomic assessment tool is a valuable resource for evaluating the design and arrangement of workstations, identifying potential ergonomic risks, and improving the health and safety of workers. Such tools help to identify physical and environmental factors that can contribute to musculoskeletal disorders (MSDs) and other health issues.Numerous studies have demonstrated the effectiveness of ergonomic assessment tools in identifying and mitigating ergonomic risks in various workplaces[12, 13]. ergonomic assessment tools can be tailored to specific industries, job types, or work environ-

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ments, making them more useful and applicable for different workplaces. For example, the Computer Workstation Ergonomics Self-Assessment Checklist is widely used to assess the ergonomic risks associated with computer-based workstations in healthcare settings[14].Discomfort symptoms in the context of work-from-home refer to physical sensations or feelings of unease, pain, or discomfort experienced by individuals while performing their work activities at home. These symptoms can manifest in various parts of the body, such as the neck, shoulders, back, arms, wrists, and legs, and may include sensations of muscle stiffness, soreness, tension, numbness, tingling, or a general feeling of discomfort[15, 16, 17].

To date, limited research has focused specifically on the ergonomic risk factors and body discomfort experienced by workers in their home workstations during the COVID-19 pandemic. There is a critical knowledge gap regarding the prevalence and severity of MSDs and body perceived discomfort in work from home settings, as well as the specific risk factors associated with these conditions. The study will utilize an ergonomic assessment tool to evaluate the workstation that contribute to MSDs and body discomfort [18, 19]. By gaining a deeper understanding of these risk factors, effective interventions and recommendations can be developed to promote healthier and more ergonomic home work environments for remote workers

The aim of this study is to survey the conditions of workstations at home and describe the risk factors for discomfort among workers during the COVID-19 pandemic when working from home.

2. Methods

2.1 Study design

This study isan observational cross-sectional. The study was carried out for seven-monthperiod (January to July 2020). The data were obtained through an anonymous online questionnaire (Google Forms) in Thai language. The time of distribution was July 2020. The questionnaire was posted on social networks such as Facebook and LINE application. According to the criteria, the data comes from 303Thai participants. The sample size was calculated using the following formula[20]:

$$n = \left(\frac{Z^2_{1-\frac{\alpha}{2}} \cdot p(1-p)}{d^2} \right) \quad (1)$$

Where: $Z_{1-\frac{\alpha}{2}} = 1.96$ (C.I. 95%, $\alpha = 0.05$)

$p = 0.76$ (the ratio of affected population from COVID-19 in China[21].)

$d = 0.05$

The results determined a sample size of 281. With a consideration of a 10% dropout rate, the authors expected 310 participants. The inclusion criteria for the study were as follows: 1) male or female aged 20 years, 2) working from home during the pandemic, 3) using a computer (PC only) for work, 4) able to communicate in Thai, and 5) must respond to the consent form. The exclusion criteria were as follows: 1) workers who did not complete the questionnaire and 2) those who did not want to participate in the study (for ethical purpose). The content validity of all questions was checked by three experts in the fields of occupational health, public health, and health science. The item-objective congruence (IOC) of the content validity ranged from 0.8 to 1.0.

2.2 Computer workstation checklist

The questions were distributed in the Thai version of the Computer Workstation Ergonomics Self-Assessment Checklist, which was originally developed by the National Institutes of Health, Office of Research Service, Division of Occupational Health and Safety, USA[14]. The checklist is commonly used to assess workstations for proper comfort and performance. Basically, this checklist has been designed for use as a self-assessment on individual's behalf. This means general people are able to assess their own workstation and perform simple adjustment to reach comfort. Since, this study was conducted via online, the authors intended to ensure that the participants can undertake the questions. Therewere 5 sections with 19 questions in total.All questions were dichotomous, requiring a Yes or No response.

2.3 Discomfort Survey

The discomfort survey used in this study was adapted from the MSD Prevention Guideline for Ontario, Part 3B: MSD Prevention Toolbox[22]. Participants were asked to rate their level of discomfort during the work from home period from January to July 2020 by checking off a box. In this study, participants were asked to rate their discomfort levels for three body region, which were the highest perceived discomfort [17]: neck, lower back, and legs, using a scale of 0 to 10, where 0 indicates no discomfort and 10 indicates the worst discomfort. The data were analyzed using multiple linear regression.

2.4 Analysis

All the data were collected via Google Forms and exported into R version 4.2.3 for statistical analysis. Descriptive analysis was used to summarize the data distribution. To evaluate the relationship among demographic information, workstation assessment, and discomfort scales, we conducted multiple linear regression analysis by including all factors for model generation, and we considered a p-value of 0.05 as statistically significant.

2.5 Ethics

The protocol for this study was approved by the Ethics Committee on Research of School of Health Science, Sukhothai Thammathirat Open University (STOU), Thailand (IRB-SHS 2020/1004/69). All ethical issues were complied with accordingly, and all participants were fully informed about the study and asked for their consent prior to participation.

3. Results

3.1 Demographic

The demographic information of the participants is presented in Table 1. A total of 303 participants were included in the study (97.7%), of whom 192 (63.4%) were female, and 111 participants were male. The average age of the participants was 34.28 years (SD ± 8.28), with the highest age range being 30-39 years old (44.22%). Most participants were single (74.59%), held a master's degree (38.61%), and spent 5-8 hours per day looking at a computer screen (68.32%).

3.2 Self-assessment checklist

Table 2 displays the results of a questionnaire given to study participants regarding their workstation assessment. The checklist includes five sections: chair (C), keyboard and mouse (KM), work surface (WS), breaks (B), and accessories (A).

In the chair section, it is revealed that 77.23% of participants had their feet fully supported by the floor when seated, while only 34.32% sat without feeling pressure from the chair seat on the back of the knees.Around half of the participants possessed other items about chair such as adjustability (45.21%), back support (53.14%), and armrest (52.81%).

Regarding the keyboard and mouse section, 88.78% of participants reported being able to position frequently used items within their reach range, while 84.16% had their mouse at the same level and close to the keyboard. Other factors such as having straight wrists and relaxed upper arms while using the keyboard and mouse (60.73%), having the keyboard, mouse, and work surface at elbow height (67%), and the mouse being comfortable to use (71.95%) were also reported by a significant proportion of participants.

In the work surface section, 92.74% of participants had their monitor positioned directly in front of them, but only 38.28% had appropriate lighting for reading and writing documents. Other factors related to the work surface, such as having a glare-free monitor/work surface (69.31%), the monitor height being below eye level (67.33%), and the monitor being placed at least an arm's length away (75.25%), were reported by more than half of the participants.

In the breaks and accessories sections, 63.04% of participants reported using a headset or speakerphone while talking on the phone, 63.70% had a document holder, 63.37% took postural breaks every 30 minutes, and 75.91% performed regular eye breaks when looking at the monitor.

According to the multiple linear regression analysis, the result of neck discomfort is significantly associated with having no posture break every 30 minutes ($p < 0.05$), which seems to be a significant discomforting factor for back and legs as well. The results have also showed that having no armrest and straight wrist posture are associated with back discomfort.

3.3 Discomfort scale

The participants were asked to rate their discomfort into 0-10 scale regarding working from home. Figure 1 presented the discomfort results of participants for their neck. The number and percentage of responses were also showed in the figure. The top three discomfort scales under working from home condition were 2, 7, and 3, respectively.

Figure 2 presented the discomfort results of participants for their lower back. The top three discomfort scales under working from home condition were 7, 8, and 2, respectively.

Figure 3 presented the discomfort results of participants for their legs. The top three discomfort scales under working from home condition were 1, 0, and 2, respectively.

4. Discussion

The present study aimed to assess the working conditions at home and the resulting levels of discomfort among workers during the COVID-19 pandemic. The findings revealed several significant results that contribute to our understanding of ergonomic risk factors and their impact on body discomfort in the home work environment. Additionally, we will discuss the hypotheses that explain the findings and provide a comparison to previous studies, as well as implications and suggestions for further research. Regarding the working conditions at home, the study highlighted the need for improvement in the "chair" section, with the highest number of participants (65.68%) reporting that they were not able to sit without feeling pressure from the chair seat on the back of their knees. The immediate improvement would be to add a back support and optimize the seat pan to allow for better posture and comfort[23, 24, 25].By implementing these modifications, workers can reduce the risk of developing long-term physical problems associated with poor sitting posture[17].

Similarly, 61.72% of participants reported that they did not have appropriate light for reading or writing documents. This can be addressed by adding a desk lamp, placing it on the left side if the participant is right-handed, and on the right side if the participant is left-handed. This aligns with previous research that emphasizes the importance of appropriate lighting in

Table 1. Demographic variables

Characteristics	n	%
Gender		
Male	111	36.63%
Female	192	63.37%
Age (years)		
20-29	99	32.67%
30-39	134	44.22%
40-49	50	16.50%
50-59	20	6.60%
Mean (± SD)	34.28 (±8.28)	
Marital status		
Single	226	74.59%
Married	68	22.44%
Widowed/Divorced/During a separation	9	2.97%
Education		
bachelor's degrees or lower	106	34.98%
master's degree	117	38.61%
Doctorate degree	80	26.40%
Hours/day on computer screen		
1-4	33	10.89%
5-8	207	68.32%
9-12	59	19.47%
>12	4	1.32%

Table 1. Demographic variables

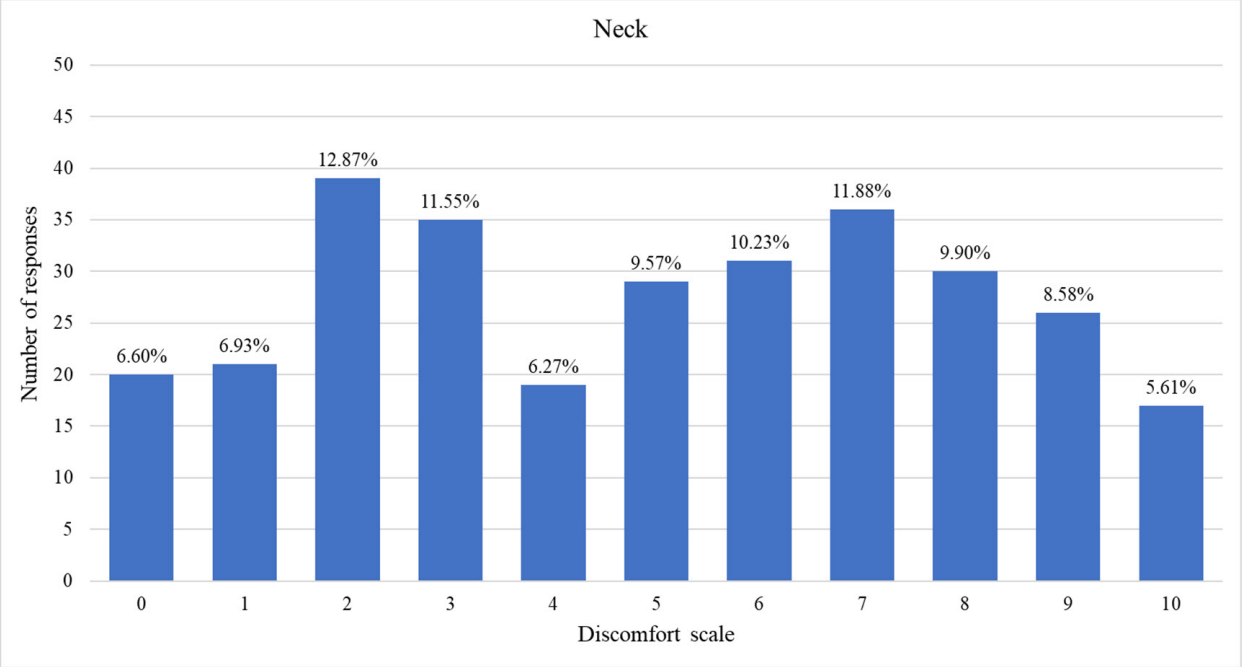

Figure 1: Self-reported discomforts regarding working at computer workstation: Neck

reducing eye strain and improving visibility during work tasks[26].Adding a desk lamp and positioning it correctly based on the participant's dominant hand can alleviate this issue[27].

It is recommended that they obtain a regular adjustable chair to allow for proper adjustments to be made to fit the individual's body type and height. This will not only improve comfort but also prevent long-term physical problems associated with poor posture[24].

The multiple linear regression analysis revealed several significant factors associated with discomfort in various body regions among participants. The findings support previous studies conducted in other coun-

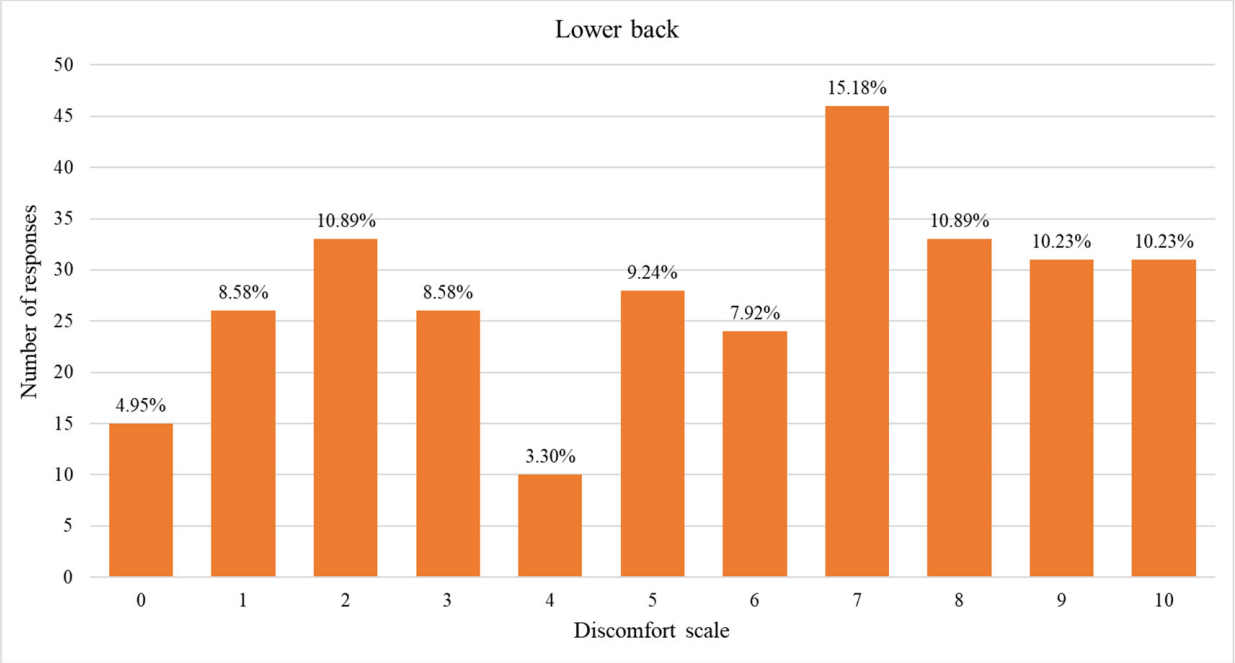

Figure 2: Self-reported discomforts regarding working at computer workstation: Neck

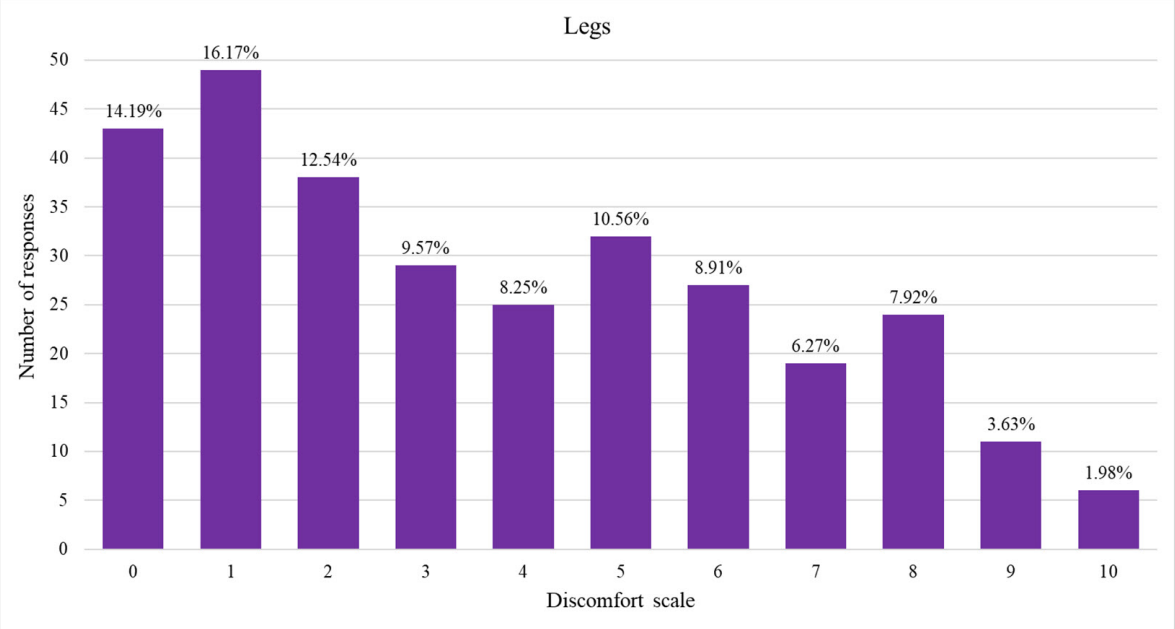

Figure 3: Self-reported discomforts regarding working at computer workstation: Legs

tries and provide valuable insights into ergonomic risk factors and their impact on specific body regions[7, 28, 29, 30]. For instance, the study found that gender and taking postural breaks every 30 minutes were significantly associated with neck discomfort. Specifically, female participants who did not take postural breaks were more likely to report neck discomfort. This emphasizes the importance of incorporating regular postural breaks, especially for female workers, to prevent the development of neck discomfort.

Moreover, the analysis revealed that the absence of armrests, improper wrist positioning and upper arm relaxation when using keyboard and mouse, and not taking postural breaks every 30 minutes were significantly associated with lower back discomfort ($p < 0.05$). These findings underscore the importance of providing ergonomic equipment such as chairs with armrests and positioning keyboard and mouse in a way that ensures proper wrist positioning and upper arm relaxation. Additionally, it is crucial to incorporate reg-

ular postural breaks in work routines to alleviate and prevent lower back discomfort. It is also worth noting that placing a keyboard on an elevated surface, such as its legs, can lead to awkward wrist angles, which can further exacerbate lower back discomfort.

Finally, the analysis suggests that taking postural breaks every 30 minutes was the only significant factor associated with legs discomfort ($p < 0.05$). This highlights the importance of incorporating regular postural breaks to relieve pressure on the legs and prevent discomfort in this region[31, 32]. In comparing our findings to previous studies, we observed consistent patterns and associations between ergonomic risk factors for computer workstation and body discomfort. This strengthens the validity of our results and contributes to the existing body of knowledge on ergonomic risks in the home work environment. However, it is important to note that our study specifically focused on the unique context of the COVID-19 pandemic, which necessitated remote work arrangements. This distinguishes our findings from previous studies conducted in traditional office settings.

Implications of this study are twofold. Firstly, it emphasizes the need for organizations and employers to prioritize the implementation of ergonomic interventions and guidelines for workers who continue to work from home. These interventions should address the identified risk factors, such as improper seating, inadequate lighting, and the absence of adjustable furniture. By providing the necessary support and resources, employers can promote a safe and healthy work environment that reduces the likelihood of discomfort and musculoskeletal issues among workers.

Secondly, the study highlights the importance of individual awareness and self-care in the home work environment. Workers should be encouraged to be proactive in optimizing their workstations and incorporating regular postural breaks into their routines. This can help alleviate discomfort and improve overall well-being.

5. Conclusion

In conclusion, the study underscores the importance of optimizing the work environment at home to ensure better health and comfort for remote workers. Failure to properly design and arrange the workstation could lead to discomfort and pain in various body regions such as the neck, lower back, and legs. The study highlights that chair height adjustment was the most common ergonomic issue, which can be easily resolved by providing appropriate ergonomic equipment like an adjustable chair or a footrest. Furthermore, the lack of a footrest was associated with lower back discomfort, emphasizing the importance of proper foot support to alleviate pressure on the lower back. Additionally, the study stresses the significance of taking regular postural breaks every 30 minutes in preventing discomfort in the neck, lower back, and legs. Employers should prioritize providing ergonomic equipment and encouraging regular postural breaks to foster a safe and healthy work environment for their workers. Overall, addressing ergonomic issues and promoting regular postural breaks can result in improved well-being and productivity for remote workers.

6. Limitations

It is important to note that this study utilized a cross-sectional design, which means that it is difficult to establish a cause-and-effect relationship between ergonomic-related discomfort and workstation issues. There may be multiple factors contributing to the workers' discomfort, making it challenging to pinpoint a single underlying cause with certainty. Therefore, caution should be noted when interpreting the results of this study.

7. Conflicts of interest

The authors declare no conflicts of interest

8. Funding

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Methodological Framework for Evaluating Cost-Effective Energy and Climate Measures in Building Clusters

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Abstract

Building renovation and energy-efficient retrofitting is a growing concern in many building stocks to improve the energy performance and energy-related greenhouse gas (GHG) emission reductions. This paper aims to present the methodological framework for energy and climate change mitigation planning in building clusters. The proposed methodology includes building energy modeling and marginal abatement cost (MAC) curve. It enables to simulate building energy use and GHG emissions associated with energy retrofit measures (ERMs) and to evaluate the cost-effectiveness. The relationship between the cost and emission reduction potentials is presented in terms of a MAC curve. Using a case study of an educational building in Bangkok, Thailand, the energy performance of four ERMs was simulated and a MAC curve was constructed. Findings showed that the baseline emissions are 310 tCO_2e and total emissions from implementing four ERMs are 250.64 tCO_2e. The improvement of air-conditioning systems contributed the largest share of mitigation potential and was followed by measures relating to building envelopes, building energy management systems, and lighting. On the cost-effectiveness, switching to efficient lighting showed the highest cost-savings of 84.59 US$ per tCO_2e. Other ERMs delivered the cost-savings from 50 to 63 US$ per tCO_2e. The proposed methodological framework would support the decision-making for the implementation of energy and climate planning at various scales from an individual building to an urban area.

Keywords: Building energy performance, Energy modeling, Energy planning, Marginal abatement cost curve

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1. Introduction

Globally, local and national governments have committed to reducing greenhouse gas (GHG) emissions. The commitment is reflected in various international agreements, for example, the Paris Agreement and the 17 UN's Sustainable Development Goals (SDGs). The achievement of these global agreements will have to come from both developed and developing countries. Thailand has announced the transition towards carbon neutrality by 2050 and net zero emissions by 2065 at the COP 26 in Glasgow in 2021. To achieve such ambitious goals, energy and climate change planning needs to be revised in all sectors at various levels. The role of building sector is well recognized in addressing energy and climate challenges and the transition to low-carbon society [1], [2]. Building sector represents high potential to implement energy-saving and climate change mitigation measures through energy retrofit measures (ERMs) and renewable energy technologies (RETs).
In Thailand, the building sector, including residential buildings and commercial buildings, represents approximately 50% of the total electricity consumption and the remaining shares are for industrial sector and others. Existing building stocks are responsible for a large amount of energy use and a significant share of total GHG emissions. Decision-makers need to decide on measures or options to be implemented based on information about the potential of abatement costs, energy usages, and GHG emission reductions. In the

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literature, a marginal abatement cost (MAC) curve is an efficient method that includes information on cost-effectiveness and potentials of mitigation measures [3], [4], [5], [6], [7], [8], [9].

MAC curves help decision-makers prioritize different measures or options based on the cost-effectiveness of ERMs, RETs, and other promising technologies. MAC curves have been gaining popularity in the area of energy and climate change planning since McKinsey & Company has published the MAC curves in 2009 [4], [7]. In Thailand, a recent work related to a MAC curve was performed by [10] to determine MAC of electricity generation from RETs. Previously, [11] presented a MAC curve for residential and building sectors in Thailand using the Asia-Pacific Integrated Model/Enduse (AIM/Enduse) to assess the energy demand and GHG emissions, and mitigation potentials from a country perspective. However, few works have been done and still limited at the building cluster level. Even previous studies have confirmed that energy efficiency improvements and RETs are the main mechanisms to reduce energy use and GHG emissions in Thailand, especially to meet Thailand's Nationally Determined Contribution target [3], [12].

This paper aims to propose a methodological framework for cost-effective energy technologies and climate change mitigation measures in building clusters, for example, university campuses. The contribution of this paper is to provide a methodology for energy and climate planning. It helps to analyze different ERMs and to visualize cost-effective energy and climate measures. The proposed methodology can be applied at various scales from an individual building to building cluster or even a whole urban area. In this paper, the proposed methodological framework was applied to an educational building as a case study. The analysis of a case study focused on answering a key question relating to ERMs of educational buildings in terms of energy savings and cost-effective GHG emission reduction potentials.

2. Marginal Abatement Cost Curves

A MAC curve is a visualization tool of the GHG abatement or mitigation potentials. It illustrates a function of abatement costs and shows mitigation measures in the order of cost-effectiveness. MAC curves have been used to support energy and climate planning at various economic sectors and scales but commonly at the country level, such as [6, 7, 9]. There have been the attempts to develop and construct MAC curves for global [4], cities [13], and building sector [1], [3], [11]. A previous study by [7] described the details of existing MAC curves from both theoretical and application aspects. A study by [1] showed that there are two approaches to calculating MAC curves in the context of building sector level, including static and dynamic MAC curves.

MAC is calculated by the differences between cost in a baseline case and mitigation case divided by the differences between GHG emissions. The MAC equation can be expressed in (1). The calculations of MAC for each ERM (i) are summarized in (1–4).

$$MAC_i = \frac{(C_{i,ERM} - C_{i,Baseline})}{(EM_{i,Baseline} - EM_{i,ERM})} \quad (1)$$

where: MAC_i is marginal abatement cost of each ERM (US$/tCO$_2$e), C refers to total discounted costs, EM represents total GHG emissions (tCO$_2$e), and baseline and ERM refer to baseline scenario and mitigation scenario. Then, C and EM can be calculated as follows:

$$C_i = \sum_{t=0}^{T} \frac{IC_i, t}{(1+r)^t} + \frac{MC_i, t}{(1+r)^t} + \frac{FC_i, t}{(1+r)^t} \quad (2)$$

$$EM_i = \sum_{t=0}^{T} \frac{AE_i, t}{(1+r)^t} \quad (3)$$

where: IC is annualized investment cost, MC is annual maintenance cost, FC is annual fuel cost, and AE is annual GHG emissions. t refers to time in years and r is discount rate. It should be noted that T refers to a period of lifetime of ERM (in years), for example, T=25 for solar PV rooftops. The annualized investment cost (IC) is calculated by (4).

$$IC_{i,t} = INV \cdot r \cdot \frac{(1+r)^n}{(1+r)^n - 1} \quad (4)$$

where: INV is the investment cost of ERM (e.g., high energy efficient appliance, building envelope retrofit, solar hot water, heat pump, etc.) and n is the economic lifetime of the ERM.

3. Methodological Framework

This section presents a proposed methodological framework and data collection. Fig. 1 illustrates the proposed methodology for planning energy and climate change mitigation for building clusters. The research approach consists of three main steps.

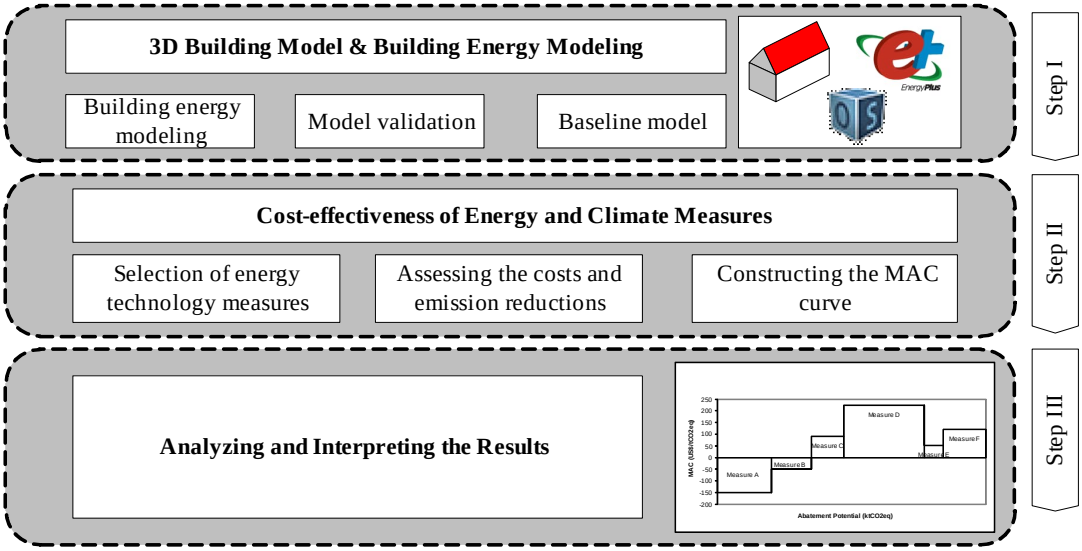

Figure 1. Methodological framework for evaluating cost-effective energy and climate measures.

3.1 Step I: Building Energy Modeling

The first step is the simulation of building energy using physics-based building energy modeling. The building performance simulation (BPS) enables to simulate the energy performance and indoor environmental quality (e.g., thermal comfort and indoor air quality) as well as integrated renewable energy systems with energy storage. BPS is a widely accepted technique to test, analyze, and optimize energy and climate strategies. The scope of this study is focused on energy performance of a building only. However, other building performance aspects, such as thermal comfort, can be extended in the BPS module with various simulation tools. The EnergyPlus through OpenStudio platform was used as a building energy model to simulate the energy use. EnergyPlus is a dynamic and whole-building energy simulation [14]. It is a widely accepted and well-recognized BPS tool that simulates hourly energy use profile of a building or a group of buildings [15]. Various studies describe detailed mathematic equations used in EnergyPlus such as [14], [16], [17]. Then, a building energy model is validated by comparing simulated results of a reference building with measured data. The relevant data used for BPS in this study are presented in a case study section.

3.2 Step II: MAC Curves

This step aims to construct a MAC curve based on a quantitative basis of different or selected ERMs. The building energy modeling in Step I provides main inputs for constructing a MAC curve of ERMs. MAC curves can be constructed with either a model-based approach or an expert-based approach [1], [3], [8], [9]. The model-based approach was applied to construct a MAC curve

for a case study building. This approach derives the costs and energy-related GHG emission reduction potentials from building energy simulations or energy model runs [8]. The advantage of a model-based MAC curve is that the energy use and mitigation measures are assessed together by a simulation of energy flows in a reference building. Thus, it helps to avoid inconsistencies and allows interactions between different measures [7], [13]. To construct a MAC curve, first, a baseline was determined for energy use and GHG emissions. Second, a range of ERMs was identified. Then, calculating the MAC of each mitigation measure or ERM follows (1–4), as mentioned earlier. Third, the costs and mitigation potentials of each ERM were combined to form a MAC curve. An example of MAC curve and relevant data is presented in the case study section.

3.3 Step III: Analyzing and Interpreting Results

The interpretation of MAC curve is also an important step for understanding of results and leading to decision-making. A MAC curve is a useful technique for screening and ranking mitigation measures, according to their costs and abatement potentials from lowest to highest cost-effectiveness. Each measure is presented along the curve plot. The x-axis is the GHG emission mitigation potential and the width of each step represents the abatement potential of a measure. The y-axis is the MAC of a measure and the height of each step is the net present cost of a measure over its lifetime. The negative values on the y-axis reflect the cost savings, whereas positive values reflect the measures having costs that exceed their benefits. The cost savings are associated with energy savings, as well as GHG emission reductions [13]. Findings from Step III can be used to identify the measures to be implemented to achieve the energy and climate goals.

4. A Case Study

To provide an illustrative example, a case study building is located in Dhurakij Pundit University, Bangkok, Thailand. The building is a six-story building with a total floor area of about 10,808 m^2. It was built in 1992. The area consists of the air-conditioned (AC) area of 6,859 m^2 and the non-AC area of 3,949 m^2. Building envelope materials include masonry walls, precast panels, and glass walls. The roof material is 4-mm metal sheets. The window-to-wall ratio of the building is 0.234 (North), 0.234 (South), 0.211 (East), and 0.211 (West). The building includes classrooms and offices and operates approximately 13 hours per day. The measured electricity consumption was 775,500 kWh/year or 71.75 kWh/m^2 year in 2018 [17]. The study used the year 2018 as a base year for simulation due to the building was in full operation before the COVID-19 pandemic. Fig. 2 shows the 3D representation of a case study model used in Step I. Calculation of a MAC curve requires a wide range of data, including building energy performance, technology characteristics in baseline and mitigation scenarios, and economic characteristics. Data on building geometry, building envelopes, and technical issues of a case study building are taken from [17]. Data related to economics and cost inputs of ERMs are taken from the literature [3], [4], [11], [13].

Table 1. The investment required to deliver energy saving (US$:kWh)

Category	Cost to save energy (US$/kWh)
Heating ventilation and air conditioning (HVAC)	0.201
Lighting	0.028
Building energy management systems (BEMS)	0.043
Other initiatives, which were not commonly found across the commercial building retrofit projects	0.168
Total	**0.440**

(source: [3])

The validation showed that the simulated annual electricity consumption is 768,899 kWh, which is 0.85% different when compared with the measured data. The simulated results revealed some differences in April, September, and December because of assumptions related to occupancy schedules and spaces, usage schedules, and operating hours of major equipment. The measurement was recorded in terms of the total electricity consumption of a building. The measured data were not divided into different end-users. The simulated results were able to report the energy use by services, such as HVAC (Heating, Ventilation, and Air-conditioning) and lighting, which is helpful when simulating with proposed measures.

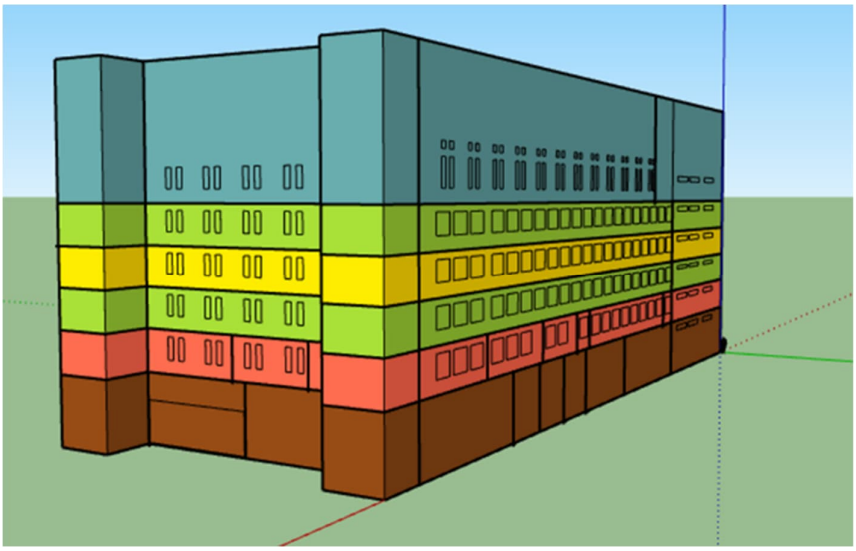

Figure 2. 3D simulation model of a case study building. Adapted from [17].

Since this work is an ongoing work and due to data available, a MAC curve was presented with limited measures. These measures were classified into four groups: ERM1(HVAC); ERM2 (Building envelope improvement); ERM3 (Lighting); and ERM4 (BEMS: Building energy management systems). It is well recognized that the improvement of HVAC systems is the most dominant ERM for buildings in Thailand. ERM2 included installation of wall insulation and replacement of glazing to Low-E with 6 mm thickness. ERM3 and ERM 4 were replacement of inefficient lightbulbs with high-efficiency lightbulbs and installation of BEMS. Results from energy modeling showed that ERM1 presents the highest energy savings, accounting for over 50% of total energy savings and followed by ERM2 (24.75%), ERM4 (11.96%), and ERM3 (10.15%), respectively. The modeling results were in line with the previous studies in [3], [11], [17], [18].

Also, findings showed that the baseline emissions are 310 tCO_2e and total emissions from implementing four ERMs are 250.64 tCO_2e.

A MAC curve was created based on modeling results and associated costs to determine the cost-effectiveness based on mitigation potential of individual ERM. The analysis was focused on assessing and comparing the selected energy retrofit measures in a case study building. Fig. 3 illustrates the MAC curve of a case study building. It shows the economic performance and abatement potential of each ERM. Results were ranked in ascending cost order. All ERM of a case study building provided negative value. Results were suggested that the cost savings overcome the investment required. These findings were agreed with other findings, as in [4].

According to Fig. 3, ERM relating to HVAC systems provides the largest contribution to emission reductions. The improvement of lighting has the highest return on investment. ERM related to the control of building operations using BEMS showed a potential for cost-effectiveness close to HVAC systems. This is due to the modeling assumptions, even BEMS are not widely implemented in buildings in Thailand at the moment but there are growing interests in installing BEMS in various buildings to support smart building projects. BEMS are computer-based control systems that control and monitor the mechanical and electrical equipment in buildings such as ventilation, heating, lighting, power systems, and so on. BEMS connect the building services plant back to a central computer to enable control of on/off times, humidity, temperatures, and so on. [19, p. 15]. Typical ways to access BEMS are presented in Fig. 4. BEMS enable users to monitor energy consumption, identify waste, and highlight areas for improvement and benchmark consumption against other similar buildings or organizations.

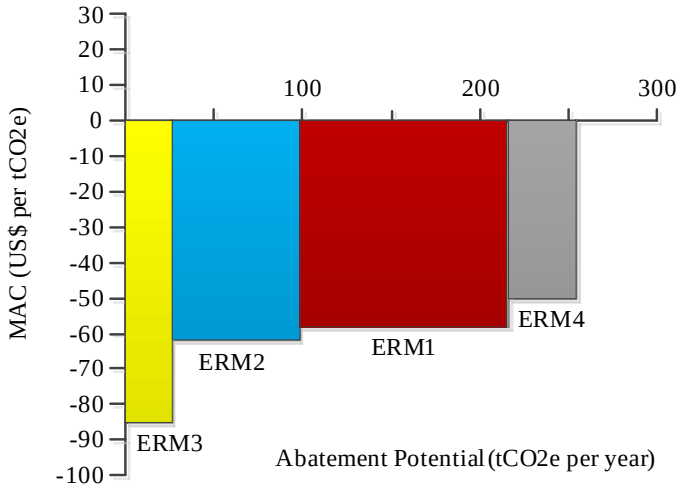

Figure 3. MAC curve for a case study building.

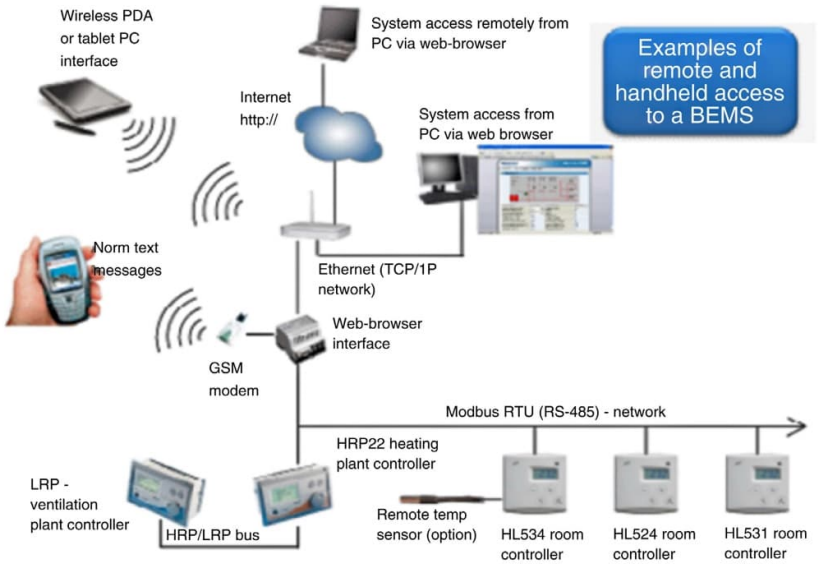

Figure 4. Typical BEMS user interfaces [19, p. 19].

5. Conclusions

Building sector represents significant energy use and GHG emissions. This research is an ongoing work. Thus, common ERMs were included in the analysis. Using a case study building, a building energy model and a MAC curve were developed to provide decision support into the relationship between the GHG emission abatement potentials and the cost of each ERM. Findings from a case study showed that all ERMs provide negative values. The negative MACs show not only positive financial feasibility and net economic savings from the investment but also reduced impacts on the environment. The proposed methodology integrated with BPS and MAC curve techniques can be applied to develop energy and climate planning for any building cluster and can extend to district and urban levels. However, the limitation of the proposed methodology is that it covers only the building sector. For district or urban areas including other sectors, such as industrial and transport sectors, additional tools will need to be integrated with the proposed methodology. It would also provide a framework for the interaction and achievement of SDG 7 (Affordable and Clean Energy), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action).

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Causal Model of Environmental Conservation Behaviors of Praboromarajchanok Institute Students

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Abstract

This research aims to: 1) study the direct and indirect influences of factors affecting the environmental conservation behaviors of Praboromarajchanok Institute students; and 2) develop a causal relationship structure model of the environmental conservation behaviors of students in Praboromarajchanok Institute by identifying elements from the theories of planned behavior, protection motivation theory, and value-belief-norm theory. The sampling for this survey research comprises 480 students from 8 colleges of the Praboromarajchanok Institute, which were obtained by multi-stage sampling. The research variables consisted of 7 latent variables, namely, attitude toward environmental behaviors, perceived efficacy in environmental behavior control, perceived threats to environmental behaviors, personal values, subjective norms, environmental behavior intention, and environmental conservation behaviors. All latent variables were measured from 24 observed variables using a questionnaire. The statistics used in data analysis were frequency, percentage, mean, standard deviation, and causal relationship structure model analysis.

The research revealed that level of environmental conservation awareness of the Praboromarajchanok Institute students was high, and the results of the analysis of the causal structure relationship for the environmental conservation behaviors of students fit with the empirical data could explain 78% of the variance in environmental conservation behaviors of students under Praboromarajchanok Institute (PBRI). Personal value had the highest effect on the environmental conservation behavior of the students, followed by environmental behavior intention, subjective norms, perceived environmental behavior control, perceived threats to environmental behaviors, and attitude towards environmental behaviors, respectively. In addition, it was found that attitude towards environmental behaviors, subjective norms, and perceived threats to environmental behaviors directly influenced environmental behavior intention. The perceived efficacy of environmental behavior control directly influenced environmental behavior intention and environmental conservation behaviors. For personal values, there was an indirect effect on environmental conservation behaviors through perceived efficacy in environmental behavior control, attitude toward environmental behaviors, subjective norms, perceived threats to environmental behaviors, and environmental behavior intention. Furthermore, environmental behavior intention was found to have a direct influence on environmental conservation behaviors.

Keywords: Causal models, Environmental conservation behaviors, Praboromarajchanok institute (PBRI)

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1. Introduction

The rapid population growth coupled with accelerated economic development in the country, driven by a lack of caution and disregard for the environment, has led to the degradation of natural resources. This, in turn, has resulted in various consequences such as global warming, greenhouse gas emissions, water scarcity, water pollution, air pollution, soil erosion, deforestation, and loss of biodiversity [1, 2]. Paying attention to environmental behavior is crucial because human behavior contributes to environmental issues. Environmental problems can be mitigated through the promotion of environmentally friendly behavior [3, 4, 5]. Addressing environmental issues depends on understanding human behavior. Individual actions can reduce environmental problems if the majority of people are concerned about the environment. This concern can extend to individual actions for environmental conservation. Environmental conservation is a positive intentional behavior toward the environment, influenced by values, beliefs, and norms, which collectively contribute to environmental conservation behaviors [6]. From the Sustainable Development Goals (SDGs), goal 12 promotes sustainable consumption and production, friendly to the environment, for sustainable development. Additionally, in the National Economic and Social Development Plan, Version 13, 2566-2570 [7], the sustainable dimension of natural resources and the environment has been addressed. Target 10 emphasizes the importance of waste and waste management for recycling and utilization, while Target 11 aims to reduce risks and impacts from natural disasters and climate change by promoting envi-

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ronmentally friendly production and consumption. All of these emphasize the significance of caring for the environment for sustainable development. Everyone must cooperate in preserving and behaving in an environmentally responsible manner. The concept and approaches to addressing environmental issues focus on instilling environmental conservation in youth and students. Promoting environmentally friendly behavior in individuals requires studying causal factors and using theories to explain environmental behaviors influenced by important factors. Examples include an individual's attitudes, subjective norms, perceived behavior control, and behavior intention in the Theory of Planned Behavior (TPB) [8]. The personal can be derived from Value-Belief-Norm Theory [9]. They specify the relevant values in three formats: biospheric value, egoistic value, and altruistic value. When individuals change the prioritization of their values, it affects the beliefs they hold about environmental behavior [10]. Perceived threats and their effects on environmental behavior can be derived from the Protection Motivation Theory, which aims to prevent disease [11]. Studying causal factors that influence environmental behavior is beneficial for practical applications in promoting higher levels of environmental behavior, especially among students [12].

Therefore, the research focus is to develop a causal model of factors influencing environmental conservation behavior among Praboromarajchanok Institute students. This group of young people plays a crucial role in promoting and maintaining environmental quality, particularly in the field of environmental health, and as role models for environmental care, to improve the quality of life for the public. Therefore, it is necessary to study and understand various factors that influence environmental conservation behavior. A causal model that aligns with empirical data can explain the relationships and influences of these factors on environmental conservation behavior, which will be beneficial for various educational institutions in guiding policies, instructional development, and activities to enhance students' environmental conservation behavior. Moreover, it will serve as a foundation for transitioning towards a sustainable green university in the future. Accordingly, this study aims to study the direct and indirect influences of factors affecting the environmental conservation behavior of Praboromarajchanok Institute students. In addition, to develop a causal relationship structure model of the environmental conservation behaviors of the students under the Praboromarajchanok Institute.This study hypothesizes that the causal relationship model of the environmental conservation behaviors of students at Praboromrajjanok Institute developed from this research is consistent with the empirical data.

2. Materials and Methods

2.1 Population and sample group

The sample size is based on the concepts proposed by Schumacker and Lomax [13], indicating that an appropriate sample size is 20 times the number of variables within the framework of this study. The current study includes 24 observed variables. Hence, this sample size is considered suitable for analysis using the AMOS software to ensure accurate estimation and representativeness of the population for this research, comprising a total of 480 samples. The population was 16,521 students at Praboromarajchanok Institute in the academic year 2021.The multi-stage sampling approach was employed in this research. In the first step, they were categorized at Praboromarajchanok Institute into two faculties: Nursing Faculty (30 colleges) and the Public Health and Allied Health Sciences Faculty (9 colleges). The sampling began with simple random sampling within the two faculties, resulting in 5 colleges from the Nursing Faculty and 3 colleges from the Public Health and Allied Health Sciences Faculty. In the next step, stratifiedrandom sampling was conducted to determine sample sizes within each collegebased on proportions calculated from the students of the 8 selected colleges. Finally, simple random sampling was employed to select specific sample groups according to the calculated proportions from each college, making a total of 480 students.The sample groups were not collected by year of study.

2.2 Research tools

The data collection tools of this study were questionnaires consisting of 8 questions about general information, 20 questions about attitudes toward environmental behaviors, 19 questions about perceived behavioral control,14 questions about personal values, 9 questions about subjective norms, 11 questions about perceived threats, 5 questions about behavioral intention, and 46 questions about environmental conservation behaviors.

The quantitative study in this step was conducted based on a survey research design. The questionnaire was used to collect data from 480 students under Praboromarajchanok. In the aspects of attitudes toward environmental behaviors, perceived behavioral control, personal values, subjective norms, perceived threats, behavioral intention, and environmental conservation behaviors. The collected data were used in a structural equation model analysis (SEM) and statistical analysis.Both causal models and structural equation models deal with relationships between variables; causal models are more specifically concerned with cause-and-effect relationships, while SEM is a broader framework that incorporates complex relationships, latent variables, and measurement aspects.

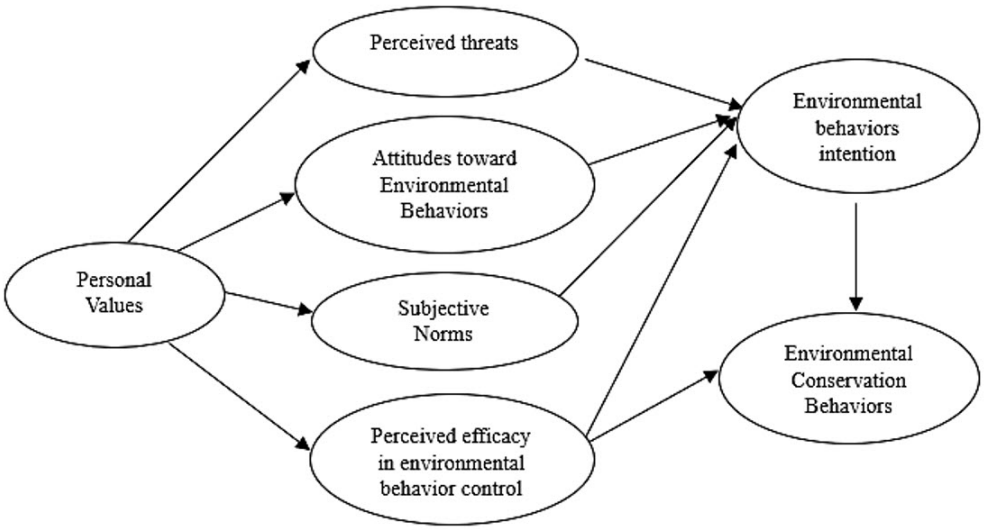

Figure 1: Research Conceptual Framework.

2.3 Research Tools Validity Test

The instruments used in the research were examined for the validity of the content by 5 experts. The attitudes toward environmental behaviors questionnaire, the perceived behavioral control questionnaire, the personal values questionnaire, the subjective norms questionnaire, the perceived threats questionnaire, the behavioral intention questionnaire, and the environmental conservation behaviors questionnaire received an I-CVI (Item Content Validity Index) of 0.80 -1.00, and the coefficient of alpha Cronbach was calculated. The confidence values were .95, .98, .92, .96, .95, .94, and .98, respectively. The item-total correlations range from .32 to .94

2.4 Research Ethics

This research has been certified in human research ethics by the Sirindhorn College of Public Health, Yala SCPHYLIRB-037/2565. Regarding the protection of information providers' rights, the researcher explained the research objectives, the right to answer or not answer any questions, the right to terminate cooperation, and confidentiality to not immediately disclose confidential information or information that could damage and destroy raw data upon completion of the data analysis. Once the informant was willing to participate in the research, a consent form was signed.

2.5 Data collection

The researcher submits research ethics for humans at Sirindhorn College of Public Health, Yala. After the review process, a formal letter was sent to the college of the selected sample group to establish communication and coordinate data collection with the designated personnel. The selected students, who voluntarily agreed to participate in the research activities and had the option to withdraw at any time during the study, were scheduled for appointments by the assigned personnel. The researcher explained the research objectives and the benefits derived from the study. Questionnaires were distributed to the selected students as part of the sample group, accompanied by instructions on how to complete them in each section. Any questions or concerns were addressed and clarified. The researcher conducted a thorough assessment of the questionnaires' completeness to ensure their validity.

2.6 Data analysis

The descriptive statistics employed were frequency, percentage, mean, and standard deviation. The Structural Equation Model (SEM) was used for model verification with AMOS (Authorization Code AMOS: d906c39e041a204b4243) by considering whether the Chi-Square value differs from zero with no statistical significance at the 0.05 level or if the Chi-Square/df value is lesser or equal to 2, the P-value with no statistical significance at the 0.05 level, the RMR (Root Mean Square Residual) value is less than 0.05, the RMSEA (Root Mean Square Error Approximation) value is less than 0.05, the GFI (Goodness of Fit Index), NFI (Normed Fit Index), CFI (Comparative Fit Index), and TLI (Tucker - Lewis Index) value higher than 0.95 [13].

3. Result and discussion

3.1 The direct and indirect influences of factors affecting environmental conservation behaviors of Praboromarajchanok Institute students

The general characteristics of the sample were 92.50% female, with a 20-year-old age of 31.00%. Most studied at the Faculty of Nursing (60.62%), 46%

had average grades 3.01-3.50, and 33.80% had an average income between 5001-10,000 baht per month. For attitudes toward environmental behaviors, perceived behavioral control, personal values, subjective norms, perceived threats, behavioral intention, and environmental conservation behaviors, all were at high levels of 4.00, 3.85, 3.76, 3.90, 4.10, 4.05, and 3.80, respectively.

The results of the linear correlation analysis among the latent variables in the causal relationship model of environmental conservation behavior among students at Praboromarajchanok Institute, consisting of 7 variables, were examined to determine the preliminary agreement of the structural equation model analysis. There were 21 pairs showed a statistically significant positive correlation with correlation coefficients of .01. The positive correlation coefficients between each latent variable in the model ranged from .554 to .775, all below 0.80. This indicates that the variables exhibit a reasonable level of correlation without any multicollinearity issues (Table 1).

Based on the elements of the model from direct and indirect variables affecting environmental conservation behaviors of students at Praboromrajchanok Institute, it was concluded that the causal structure model was able to co-describe environmental conservation behaviors by 78%. The model elements from direct and indirect variables affecting the environmental conservation behaviors of students at Praboromrajchanok Institute, it was concluded that the causal structure model was able to co-describe environmental behavior intention by 74%. The personal values were able to describe attitudes toward environmental behaviors, subjective norms, perceived threats, and perceived efficacy in environmental behavior control by 56%, 75%, 64%, and 77%, respectively (Table 2).

The personal values had a direct positive influence on attitude toward environmental behaviors, subjective norms, perceived threats, and perceived efficacy in environmental behavior control (β = .75, p < .05; β = 0.87, p < .05; β = .80, p < .05; β = 0.88, p < .05, respectively), and an indirect positive influence on environmental behavior intention and environmental conservation behaviors (β = .81, p < .05; β = .77, p < .05, respectively). The attitude toward environmental behaviors had a direct positive influence on environmental behavior intention (β = .19, p < .05), and an indirect positive influence on environmental conservation behaviors (β = .13, p < .05). The subjective norms had a direct positive influence on environmental behavior intention (β = .50, p < .05) and an indirect positive influence on environmental conservation behaviors (β = .34, p < .05). The perceived threats had a direct positive influence on environmental behavior intention (β = .18, p < .05), and an indirect positive influence on environmental conservation behaviors (β = .12, p < .05). The perceived efficacy of environmental behavior control had a direct positive influence on environmental behavior intention and environmental conservation behaviors (β = .10, p < .05; β = .18, p < .05, respectively) and an indirect positive influence on environmental conservation behaviors (β = .07, p < .05). The environmental behavior intention had a direct positive influence on environmental conservation behaviors (β = 0.68, p < .05). The environmental conservation behavior is caused by the combined influence of personal values (TE = .77), environmental behavior intention (TE = .68), subjective norms (TE = .34), perceived efficacy in environmental behavior control (TE = .32), attitude toward environmental behaviors (TE = .13), and perceived threats (TE = .13), respectively. Therefore, the causal relationship structure model of environmental conservation behaviors among students at Praboromrajchanok Institute was harmonized with empirical data and could theoretically explain the relationship between the variables. This is following the research hypothesis as shown in Figure 2.

3.2 The causal model analysis examining environmental conservation behaviors among students at Praboromrajchanok Institute

In this research, the researcher used path analysis of the structural equation. The model was adjusted to be consistent with the empirical data. The results of an index analysis were used to verify the consistency and harmony of the model with the empirical data. The results of the harmonization assessment were χ^2 = 115.91, df = 96, relative χ^2 = 1.21, p = 0.08, RMSEA = 0.02, RMR = 0.01, GFI = 0.98, NFI = 0.99, TLI = 0.99, and CFI = 1.00.

Regarding the method of parameter estimation, the composition weight of related variables in the causal relationship model of environmental conservation behavior among students at Praboromarajchanok Institute was found. The intention towards environmental behavior, which can be measured by five observable variables, including the intention to participate in environmental conservation activities (INT1) (β = 0.856, p < .05), the intention to consume environmentally friendly products (INT2) (β = 0.867, p < .05), the intention to manage waste (INT3) (β = 0.884, p < .05), the intention to conserve energy (INT4) (β = 0.819, p < .05), and the intention to use resources efficiently (INT5) (β = 0.862, p < .05), has a direct positive influence on environmental conservation behaviors. It indicates that students with higher intentions or motivations to act for the environment are more likely to exhibit high levels of environmental conservation behaviors. Furthermore, students' intentions to display environmental behaviors occur when they have evaluated that the outcomes of their actions are positive. The behavior is a result of the students' intention or willingness to act or not act under their own self-control and is not determined by emotions or a lack of consideration before making decisions, in line with

Table 1. The linear relationship between latent variables in the causal relationship model of environmental conservation behavior of students under the Praboromrajchanok Institute

	ATTITUDE	CONTROL	VALUE	NORM	THREAT	INTENSION	BEHAVIOR
ATTITUDE	1						
CONTROL	.729**	1					
VALUE	.554**	.673**	1				
NORM	.602**	.744**	.661**	1			
THREAT	.573**	.654**	.646**	.711**	1		
INTENSION	.627**	.697**	.672**	.775**	.673**	1	
BEHAVIOR	.602**	.705**	.679**	.775**	.611**	.771**	1

** Statistically significant at the level .01

Table 2. Statistical values of the influence analysis of variables and the conformity index in the causal model of environmental conservation behaviors of students under Praboromrajchanok Institute

Variable	Attitude			Norm			Threat			Control			Intention			Behavior		
	DE	IE	TE	DE	IE	TE	DE	IE	TE	DE	IE	TE	DE	IE	TE	DE	IE	TE
Value	0.75		0.75	0.87		0.87	0.80		0.80	0.88		0.88		0.81	0.81		0.77	0.77
Attitude													0.19		0.19		0.13	0.13
Norm													0.50		0.50		0.34	0.34
Threat													0.18		0.18		0.12	0.12
Control													0.10		0.10	0.25	0.07	0.32
Intention																0.68		0.68
R-Square		0.56			0.75			0.64			0.77			0.74			0.78	

$X^2 = 115.91, df = 96, relative X^2 = 1.21, p = 0.08, RMSEA = 0.02, RMR = 0.01, GFI = 0.98, NFI = 0.99, TLI = 0.99, CFI = 1.00$

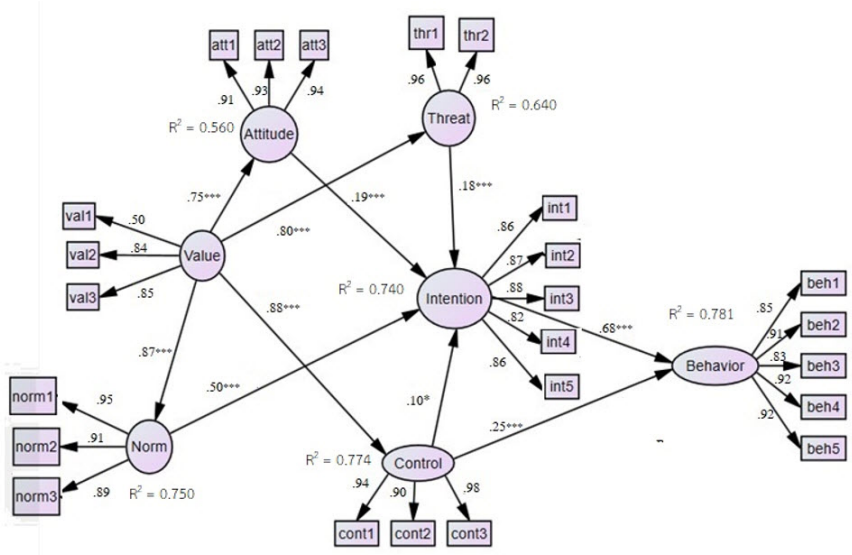

Figure 2: The result of examining the consistency of the linear structural relationship model of environmental conservation behaviors of students under the Praboromrajchanok Institute.

Ajzen's theory (2006). The stronger and more certain individuals' intentions are, accompanied by sufficient information and great efforts, the higher the likelihood of them engaging in environmental behaviors. Consistent with the previous studies [14, 15, 16], it was found that intentions have a direct positive influence on environmental behaviors.

The attitudes toward environmental behaviors can be measured through three observable variables. These variables, which include the affective variable (ATT1) ($\beta = 0.911$, $p < .05$), the sacrifice behavioral variable (ATT2) ($\beta = 0.934$, $p < .05$), and the cognitive variable (ATT3) ($\beta = 0.941$, $p < .05$), have no direct influence on environmental conservation behavior. However, they have an indirect influence through the mediation of environmental and behavioral intentions. This suggests that for students to exhibit environmentally friendly behavior, they need to undergo developmental interventions that promote attitudes toward environmental behavior. These interventions aim to raise students' awareness of the value of engaging in environmental behavior, which in turn stimulates their intention and determination to act on environmental conservation behaviors. This is following the planned behavior theory, which states that attitudes are the cause of behavior. A person's behavior is de-

Table 2. Statistical values of the influence analysis of variables and the conformity index in the causal model of environmental conservation behaviors of students under Praboromrajchanok Institute

Observed variable	Latent Variable			
		S.E.	C.R.	R2
Personal Values				
Egoistic values (VAL1)	0.497*	0.057	11.269	0.247
Altruistic values (VAL2)	0.841*	0.028	34.939	0.707
Biospheric values (VAL3)	0.854*			0.729
Attitude toward Environmental Behaviors				
Affect (ATT1)	0.911*	0.025	36.117	0.830
Willing to sacrifice Behavior (ATT2)	0.934*	0.023	9.186	0.872
Cognitive (ATT3)	0.941*			0.886
Perceived efficacy in environmental behavior control				
Self-efficacy (CONT1)	0.944*	0.023	40.186	0.892
Response-efficacy (CONT2)	0.901*	0.026	34.205	0.813
Controllability (CONT3)	0.982*			0.964
Subjective Norm				
Family (NORM1)	0.949*			0.900
Friend (NORM2)	0.913*	0.030	32.766	0.834
Social (NORM3)	0.887*	0.038	23.961	0.786
Perceived threats				
Perceived severity (THR1)	0.959*	0.026	38.266	0.920
Perceived vulnerability (THR2)	0.955*			0.911
Environmental behaviors intention				
Intention to participate in environmental conservation activities (INT1)	0.856*			0.732
Intention to consume environmentally friendly products (INT2)	0.867*	0.039	25.341	0.751
Intention to manage waste (INT3)	0.884*	0.039	24.536	0.781
Intention to conserve energy (INT4)	0.819*	0.042	21.705	0.670
Intention to use resources effectively (INT5)	0.862*	0.041	23.187	0.743
Environmental Conservation Behaviors				
Participate in environmental conservation activities (BEH1)	0.849*			0.720
Consume environmentally friendly products (BEH2)	0.905*	0.034	29.383	0.819
Waste management (BEH3)	0.833*	0.034	25.895	0.694
Energy conservation (BEH4)	0.924*	0.041	23.291	0.854
Effective resource utilization (BEH5)	0.916*	0.044	22.834	0.839

*Statistically significant at the level .05

termined by their behavioral intention, and behavioral intention is determined by their attitude [8].Consistent with the previous studies [16, 17], it was found that attitudes towards environmental behaviors have a direct positive influence on intention towards environmental behaviors and that intention towards environmental behaviors has a significant positive effect on behavior that supports the environment.

The subjective norms, which can be measured by three observable variables: family reference group (NORM1) (β = 0.949, p < .05), friend reference group (NORM2) (β = 0.913, p < .05), and social reference group (NORM3) (β = 0.887, p < .05). Subjective norms do not have a direct influence on environmental conservation behavior, but they have an indirect influence through the mediation of environmental behavioral intention. Subjective norms have a positive indirect influence on environmental conservation behavior, indicating that students believe or perceive conformity to reference groups, namely family, friends, and society, as desirable for promoting environmental conservation behavior and setting a good example. This motivation leads students to imitate or engage in such behaviors, resulting in environmental conservation behavior that benefits the environment, surrounding individuals, and the students themselves. This aligns with Ajzen's [13] Theory of Planned Behavior, which suggests that following group references is an individual's perception of whether other important individuals desire or do not desire them to engage in certain behaviors. This perception may or may not correspond to reality. To generate this variable, it is necessary to have basic beliefs similar to attitudinal beliefs that affect actions. These are referred to as beliefs about reference groups. When individuals perceive or recognize that influential individuals perform certain behaviors, there is a tendency for them to imitate these behaviors. In this research, the influential individuals or reference groups for students are their families, friends, and the social environment in which they reside, who consistently demonstrate environmental conservation behaviors. Consequently, this leads to the occurrence of imitative behavior, displaying environmental conservation behavior, including participation in environmental conservation activities, environmentally friendly consumption, waste management, energy conservation, and resource conservation. This finding is consistent with previous studies [18, 19, 20], which found that the subjective norm has a positive direct influence on environmental behavioral intention and an indirect influence on environmental conservation behavior.

The perceived environmental behavior control can be measured through three observable variables. These variables include self-efficacy (CONT1) (β = 0.944, p < .05), response efficacy (CONT2) (β = 0.901, p < .05), and controllability (CONT3) (β = 0.982, p < .05), which encompass both direct influence on environmental conservation behavior and indirect influence through the mediation of environmental behavioral intention. This aligns with the concept of behavior theory, which suggests that the perception of control ability plays a crucial role in the intention to act, leading to various environmental behaviors [8], and the protection motivation theory, which states that evaluating problem-solving responses that prevent hazardous situations leads to behavioral adaptation. It assesses whether individuals can change environmental behavior, supported by two factors: the belief that changing behavior can genuinely reduce environmental impacts and confidence in one's ability to change behavior [11]. This finding is consistent with previous studies [16, 21, 22], which found that students with high self-efficacy in showing environmentally responsible behaviors had higher direct effects on environmentally responsible behavior and indirectly affected environmentally responsible behavior through their intention to perform environmentally responsible behavior.

The perceived threats to environmental behaviors can be measured through two observable variables. These variables, including perceived severity (THR1) (β = 0.959, p < .05) and perceived vulnerability (THR2) (β = 0.955, p < .05), have an indirect effect on environmental conservation behavior through the mediation of environmental behavioral intention. This is consistent with Roger's (1997) protection motivation theory, which emphasizes the assessment of threats, including their sources and components, as well as factors influencing resistance to behavior change. Therefore, the perception of violence results in awareness of the dangers of not paying attention to environmental behavior. As for the perceived vulnerability of the impact of environmental behavior, it is a factor that affects students' willingness to show behavior in the environment. This finding is consistent with previous studies [23, 24], which found that the variables of perceived severity and perceived vulnerability directly influence the environmental behavioral intention to engage in environmentally responsible behavior.

The personal Values, which can be measured by three observable variables, including the egoistic values (VAL1) (β = 0.497, p < .05), the altruistic values (VAL2) (β = 0.841, p < .05), and the biospheric values (VAL3) (β = 0.854, p < .05), have a direct positive influence on attitudes towards environmental behaviors, subjective norms, perceived efficacy in environmental behavior control, and perceived threats. Moreover, personal values have an indirect positive influence on environmental behavior and conservation behavior. This research is aligned with the concept of value-beliefs-norms theory, where personal values are associated with individual beliefs and behavioral changes resulting from the perception of societal importance. It leads to awareness of the environmen-

tal impact and responsibility for the consequences of one's actions on others. Individuals who exhibit environmental behaviors are likely to have higher biospheric and altruistic values [10]. This finding is consistent with previous studies [25, 26], which found that environmental values have a direct positive influence on environmental attitudes, conformity to reference groups, perceived behavioral control, and an indirect positive influence on environmental behavioral intention and environmental conservation behavior.

The environmental conservation behaviors, which can be measured by five observable variables, include participating in environmental conservation activities (BEH1) ($\beta = 0.849$, $p < .05$), consuming environmentally friendly products (BEH2) ($\beta = 0.905$, $p < .05$), waste management (BEH3) ($\beta = 0.833$, $p < .05$), energy conservation (BEH4) ($\beta = 0.924$, $p < .05$), and effective resource utilization (BEH5) ($\beta = 0.854$, $p < .05$) (Table 3). These findings suggest that students who engage in these specific environmental behaviors are more likely to exhibit a higher level of overall environmental conservation behaviors [21, 26].

4. Conclusions

This research examined the level of environmental conservation behaviors among students at the Praboromarajchanok Institute and explored the factors influencing these behaviors. By developing a causal relationship structure model, incorporating elements from various theories, it was revealed that personal values had the strongest impact on environmental conservation behaviors, followed by environmental behavior intention, subjective norms, perceived environmental behavior control, perceived threats to environmental behavior, and attitude towards environmental behaviors. The analysis showed direct influences of attitude, subjective norms, and perceived threats on behavior intention, while the perceived efficacy of behavior control influenced both behavior intention and environmental conservation behaviors. Additionally, personal values indirectly affected conservation behavior through their influence on other variables. Overall, this research contributes to a better understanding of the determinants of environmental conservation behaviors among students, providing insights for developing effective strategies to promote sustainable behaviors.

From the study, it can be seen that altruistic values and biospheric values exert significant influence towards environmental conservation behavior. Therefore, it is essential to promote these two values among students through various activities that have been facilitated by relevant departments within the institution. This approach serves as a channel to encourage students to participate in sustainable environmental conservation behaviors. It is important to promote awareness of environmental behavioral control among students in three dimensions: self-efficacy, response efficiency, and the ability to control. This can be done by creating student experience through environmental activities within the institution. Participating in these activities gives students confidence in their ability to solve environmental problems. These hands-on experiences foster self-confidence and awareness of one's ability to manage the environment effectively. Subjective norms strengthen and foster open dialogue among friends, family, and colleagues about the importance of preserving the environment. Encourage conversations that lead to shared values and a shared commitment to sustainable behavior. Also, behavioral intentions that set concrete goals motivate individuals to set specific, attainable goals for environmental conservation efforts. The developed model can be used to benefit other organizations and educational institutions and serve as a policy framework/plan to develop effective and sustainable environmental conservation behaviors. This is helpful in explaining the factors that influence environmental conservation behavior, which lead to policy outcome, especially self-development, raising awareness of the value and taking responsibility for the consequences of their own and others' actions in the environment with the aim of promoting long-term environmental conservation behavior.

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Social Welfare Policy for Prevention and Factors Influencing the Use of Tramadol by School Children and Adolescents in Thailand.

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Abstract

Tramadol was originally an opioid pain reliever used to treat moderate-to-severe pain. Tramadol was first overused by children and adolescents all over the world to relieve mental health strain about 20 years ago, and it has since destroyed the users' mental and physical health. This article describes the findings of a study on tramadol misuse in Thailand, as well as the level of awareness about the penalties for dangerous drug misuse, legal measures to control dangerous drugs, and the factors that influence harmful drug abuse and its impact on drug users. Using quantitative research, data was obtained from young people and children. According to the data, the current situation of dangerous drug use among children and adolescents is on the rise. A poll of 257 children and adolescents found that 45.8% had limited knowledge of tramadol use, and 51.8% had a moderate grasp of legal measures. At a statistically significant level of 0.05, age, maternal order, substance use behavior, Tramadol drug selection channels (in the case of grocery shops), components chosen for use with addiction, and family ties were all factors that influenced hazardous drug misuse. Tramadol use has a harmful impact on addicts, their families, and society.

Keywords: children and adolescents, misuse of tramadol, prevention, social welfare policy

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1. Introduction

Tramadol was first used to treat moderate-to-severe pain nearly 20 years ago. Tramadol was later overused and misused by children and adolescents all over the world to relieve mental health strain which has destroyed the users' mental and physical health. Much Thai youth in the educational system used tramadol to relieve stress, which had a significant impact on their physical, mental, and educational quality, and future. To limit the spread of tramadol misuse, the Food and Drug Administration (FDA) and the Narcotics Control Board of Thailand have put many measures in place. However, the spread of tramadol misuse seems to be increasing amongst Thai youth.

Even though FDA issued strict measures in 2013 controlling the sale of tramadol to production licensees, licenses to import drugs, and pharmacists who are responsible for operating in such establishments, including those classified as "dangerous drugs" and must be sold in a licensed modern pharmacy. The medicine must be delivered by a pharmacist who has the duty to operate legally. Pharmacy licensees and pharmacists must jointly prepare a purchase and sale account that is accurate and up to date. Pharmacists must deliver medicines according to professional ethics, without prescribing the drug to those who have no medical indication, and pay the right amount for the safety of the patient. If the pharmacy does not have a license to sell modern drugs, it is punishable by imprisonment for not more than 5 years and a fine of not more than 10,000 baht. In the case of failing to make an account for buying or selling drugs, the licensee is subject to a fine of 2,000–10,000 baht. Pharmacists are fined between 1,000–5,000 baht. In the case of tramadol pharmacy (which is a dangerous drug), while the pharmacist is not on duty, the licensee is guilty and is fined from 1,000 to 5,000 baht. [1]

However, the spread of tramadol misuse seems to be increasing among Thai youth. This paper investigates the factors that lead to its abuse, tramadol misuse situations, the level of knowledge about the punishment for dangerous drug misuse, and recommendations for controlling dangerous drugs.

2. Literature review

Tramadol acts as a serotonin releaser by inhibiting serotonin and noradrenaline reuptake, whereas the O-dimethyl metabolite of tramadol (known as M1 or ODT) acts on the opioid receptor. This implies that the mechanism of action of tramadol includes both non-opioid components—that is, noradrenergic and sero-

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tonergic components—and opioid components. Intravenous naloxone has been successfully used to reverse the opioid-related respiratory depressant effects of tramadol overdose.

Symptoms following tramadol intoxication are like those of other opioid analgesics. These include CNS depression, including coma, nausea and vomiting, tachycardia, cardiovascular collapse, seizures, and respiratory depression up to respiratory arrest. Moreover, in combination with serotonergic agents (for example, selective serotonin reuptake inhibitors and monoamine oxidase inhibitors), tramadol may induce serotonin syndrome. Hyperthermia in serotonin syndrome is potentially fatal. Because of the opioid agonist activity of O-desmethyl-tramadol, tramadol may lower the respiratory rate and potentially lead to severe respiratory depression. [2]

Tramadol is used to treat both acute and chronic pain of moderate to severe intensity. Tramadol is available worldwide as a medicine. It is mentioned as a step-2 analgesic in the WHO guidelines for cancer pain relief. Tramadol is listed on several national essential medicine lists, but it is not listed on the 20th WHO Model List of Essential Medicines or the 6th WHO Model List of Essential Medicines for Children.

There is growing abuse of tramadol in some African and Western Asian countries, as evidenced by large seizures, predominantly of tablets, in North and West Africa. Abuse of tramadol has become a serious problem in several Middle Eastern countries. Data provided by the UNODC (July 2017) on global tramadol seizures show a steady rise in seizures between 2007 and 2015. Several countries have brought tramadol under some form of national legislation. [3]

Misuse of Tramadol can cause addiction, overdose, or death, especially amongst children or adults using the medicine without a prescription. Tramadol should not be given to a child younger than 12 years old or anyone younger than 18 years old who recently had surgery to remove the tonsils or adenoids. Taking tramadol during pregnancy may cause life-threatening withdrawal symptoms in the newborn. Fatal side effects can occur if you use this medicine with alcohol or with other drugs that cause drowsiness or slow breathing. [4]

Tramadol is known as "green yellow" amongst children and adolescents in Thailand because of its green and yellow capsule. They mixed Tramadol with coffee, Kratom juice, soft drinks, energy drinks, or alcoholic drinks to mimic the effects of narcotic substances. As a result, a quiet hazard of a surge in harmful drug usage among children and adolescents that is becoming a concern in Thai society. Leaving users unable to control their desires for narcotic substances. Particularly concerning is the mental health of drug addicts who need to take drugs all the time and require more. They will probably feel calm and cheerful right away, but if they take it too much or too often, it will have a direct effect on drug addicts, causing them to have deteriorating health, mood swings, and brain and nervous system damage. In addition to Tramadol, four categories of medicines are commonly misused by children and adolescents, including Prosody, Dextromethorphan, Dimetapp Elixir, and Alprazolam. Children and teenagers in Bangkok's Juvenile Observation and Protection Center had a growing tendency toward dangerous drug usage, such as tramadol, prosody, cough suppressant liquid, and so on, according to reports from the Office of the Narcotics Control Board, Bangkok. [5]

Because harmful drugs are not classified as addictive substances, Thailand lacks a systematic or evident procedure for data collection. The amount of information provided regarding the effects of medicine misuse and the observation of behavioral symptoms among individuals who use harmful drugs is extremely limited, leaving parents of children and adolescents unaware of their children's drug use. Dangerous medications, on the other hand, are inexpensive and can be obtained at any drugstore or on social media sites such as Facebook, LINE, Instagram, Twitter, or game shops. As a result of the circumstances, several Thai children and teenagers are at risk of abusing harmful narcotics.

Tramadol misuse occurred approximately 20 years ago, as evidenced by several studies in several countries, including Habib Ahmadi, Mansour Rezaie, and Jamal Hoseini. Tramadol is used. Misuse of the objective from 2005 to 2008, 294 deaths were reported with tramadol in the body, and between 2008 and 2010, patients were hospitalized due to the toxic effects of tramadol. As many as 1,023 people, most of whom use drugs to hope for suicide and use drugs. [6]

The results of an emergency patient study have been released by the United States Drug Abuse Warning Network (DAWN). Tramadol discovered that there were 15,349 emergency patients admitted to the emergency department for drug-related reasons in 2009, 16,251 in 2010, and 20,000 in 2011 (Drug Enforcement Administration. 2014). In addition, the National Survey on Drug Use and Health (NSDUH) reported that 1.8 million American youth aged 12 and older took tramadol in 2017. In 2018, 1.5 million people were counted. [7]

Elliason EK et al. [8] looked at the use of Tramadol in Ghana. 84.0 percent of the perverted adolescents in Wassa Amenfi West knew tramadol via friends and colleagues, and 69.3 percent knew tramadol. Tramadol is widely available, and 30% of people use it for sexual pleasure and enhancement.

Chikezie, U.E., and Ebuenyi, I.D. [9] did a study on tramadol use in Nigeria. The great majority of tramadol abusers in the Niger Delta were determined to be young guys. According to the information they were given, Tramadol is an opioid analgesic used to alleviate pain and aid in the recovery of consciousness.

In the region, tramadol abuse among young males is an everyday occurrence.

Several nations, including the United States of America, Canada, Sweden, the United Kingdom, the Republic of South Africa, Australia, Singapore, and Hong Kong, regulate tramadol as a dangerous substance that can only be acquired with a prescription. (Only on prescription) [10]

Despite this, the misuse of tramadol is growing all over the world, according to the World Health Organization's 2019 Tramadol-Update Review Report, which states that North Africa, West Africa, and North Africa are the most affected. Tramadol is believed to have been misused across Europe and Western Asia, resulting in the deaths of between 70,000 and 100,000 people as a result of an overdose. [11]

PatchamonSantisetsin and ChuanchomThananithisak [12] conducted a survey in Thailand to gauge public opinion on tramadol sales control methods. Selling Tramadol prompted FDA to enact regulations on tramadol distribution, although it was discovered that many people still do not comprehend the regulations, seen more as a hindrance. There was a poor level of satisfaction with the measure, which made it difficult for individuals who need tramadol treatment to acquire it.

According to literature review, tramadol abuse occurs both in Thailand and overseas. It is mostly seen in young males who hurt themselves, their families, and society. Thailand, on the other hand, still has a long way to go in terms of preventing tramadol abuse among children and adolescents.

3. Methodology

This study employs quantitative research to gather personal characteristics of sample group. The widespread use of dangerous drugs among school age children and adolescents is alarming. These factors influence the use of dangerous drugs among children and young people of school age. The effects of dangerous drugs on drug users, their families, and society.

4. Research questions

1. How popular and widespread is the taking of dangerous drugs among children and young people of school age?
2. What factors influence the use of dangerous drugs among children and adolescents of school age?

5. Sample

The sample were children and adolescents who are under control by the Regional Juvenile Vocational Training Center (RJVCT) 1-11 during 2019–2020. The RJVCT has tasks and duties in controlling, supervising, correcting, treating, rehabilitating, preventing, and developing behavior to support children and adolescents who have been sentenced or ordered by the court to receive training so that children and adolescents can return to a good people and can live a normal life in society. The inclusion criteria are children and adolescents who had been misused of tramadol behavior. The total population in the RJVCT at that time was 2,665.

By using purposive sampling to children and adolescents who had previously misused tramadol, the sample size in total were 257 children and adolescents under the control of RJVCT 1-11.

6. Measurement

The drafted questionnaire was developed based on a literature review, researcher objectives, and research questions including the experts on tramadol misused. Twenty drafted questionnaires were tested on Tramadol-addicted youngsters in Nakhon Sawan Province. The use of specific data with an estimation scale measurement is used to calculate the confidence value and use Cronbach's formula (α - Cronbach's Alpha Coefficient). Then adjust the questions with low confidence values and according to the recommendations of the experimental sample. After that, the second experimental data collection was required to check the confidence value as close to 1 as possible. The conclusion is Cronbach's Alpha Coefficient, or all items are, more than 0.7, indicating that the questionnaire had an appropriate level.

7. Data analysis

The analysis includes descriptive statistics such as frequency, percentage, mean, and standard deviation. They are employed to explain personal variables, harmful drug behaviors and drug usage, tramadol knowledge, and tramadol purchase channels.

For details on life assets, upbringing characteristics, family relationships, friendship behavior, legal opinions, and health consequences, scores for each item were calculated by using the Likert scale, which was divided into five levels as follows:

1.00 - 1.80 = lowest level
1.81 - 2.60 = low level
2.61 - 3.40 = moderate level
3.41 - 4.20 = high level
4.21 - 5.00 = maximum level

8. Hypothesis testing

This research employed inferior statistics to test the hypothesis. The independent valuables includedgender, age, education, number of household members, number of siblings, order of being a child, parent's marital status, close care parents, offense, using behavior of drug substances, level of knowledge about

the dangers of taking dangerous drugs, level of knowledge of legal measures, life assets, channels for purchasing Tramadol, ingredients selected for tramadol use, family relationship. The dependent variable was the misuse behavior of the dangerous drug tramadol.

To test the research hypothesis, the researcher performed inferential analysis. As follows, the level of statistical significance was established at 0.05:

1) Using the T-test to compare the sample's differences means to test the hypothesis about personal characteristics such as gender and criminal background, substance use behavior, and purchasing channels.

2) Using the F-test and one-way analysis of variance (ANOVA), test whether the personal factors of age, education level, number of household members, number of siblings, marital status, parents and close parental supervision, level of knowledge of the dangers of drug misuse, level of knowledge of legal measures to control dangerous drugs, life assets, which ingredient was chosen for use with Tramadol, nature of family upbringing, and family relations

3) Compare the pairwise difference of the mean by Scheffe's method to test the pairwise difference of factors influencing tramadol misuse behavior.

9. Research ethics

The researcher received the certificate of research ethics from Huachiewchalermprakiet University on 24 October 2019. Before collecting data, the researcher requested permission from the Department of Juvenile Observation and Protection, Ministry of Justice, to collect data. Before interviewing the sample, the researcher used a consent form to ask whether they were willing to provide information or not. All samples are willing to provide information voluntarily.

10. Results

Most samples are males, ages 17 to 18 years, with low educational attainment. Most of their mothers are single moms. All samples were charged with narcotics offenses. They understood that tramadol was classified as a dangerous drug.

The sample first started misusing Tramadol at the mean age of 15 years old; the minimum age is 10 years. The maximum misused was 1 tablet/capsule per time, and the maximum was 160 tablets/capsule per time. Most of them use soft drinks as an ingredient. Tramadol use was at a moderate level. They had a habit of using drugs such as cigarettes, were experienced in substance abuse treatment, knowledge about the dangers of Tramadol is at a high level, 45.8% had limited knowledge of tramadol use, 51.8% had knowledge of legal measures to control Tramadol is moderate, and the channel for purchasing Tramadol is a group of seniors or junior friends.

Life Assets or basic costs are positive factors affecting the psychological, social, and intellectual development of children and adolescents to behave in accordance with social norms, and able to live in a strong society It uses the essence of internal assets and external assets, comprising of 5 powers, self-power, family power, intellectual power, peer power and activity, and community power: The sample had life assets in terms of self-power, with an average of 3.35, which is at a moderate level. In terms of family power, the average was 3.56, which was high. In terms of intelligence building, the average was 3.00, which was at a moderate level. In terms of friend power and activity, the mean was 2.82, which is at a moderate level, and in terms of community power, the average was 3.09, which was a moderate level. (Table 1)

The sample had the caring care model with a mean of 3.90, which was at a high level; the control model with a mean of 2.48, which was moderate; the indulged model with a mean of 3.00, which was moderate; the abandoned model with a mean of 2.09, which was low; and the family relationship model with a mean of 4.03, which was a high level. (Table 2)

The other results were the sample exhibited moderate levels of friendship behavior, with an average of 2.99, opinions on the legal measure, with a mean value of 3.55, which was a high level, and the impact on their health condition during the use of tramadol, the mean was 3.25, which was a moderate level.

11. Result of Hypothesis test

The hypothesis test results are by comparing the sample mean difference with the T-test, One-Way Analysis of Variance (ANOVA), and F-test. The influences at the statistically significant level of 0.05 on tramadol misuse behaviors were age (p =.000) as shown in Table 3,

The mean difference was then compared with Scheffe's test method. The differences between pairs are as follows:

The age difference was statistically significant at the 0.05 level. There were 3 pairs, namely, the sample aged 17–18 years had behaviors of taking tramadol in the wrong way. more than the sample of 15-16-year-old. The sample aged 19–21 years had more tramadol abuse behavior than the sample aged 15–16 years. The sample aged 19–21 years old had more misuse of tramadol-type drugs than the sample aged 17–18 years.

In terms of the order of the children, there was no difference in each pair.

In terms of ingredients selected with tramadol use that were significantly different at the 0.05 level, there were 5 pairs. There was more misuse of tramadol than in the mixed drink sample. The sample selected to mix with drinks and eat whole tablets or capsules (does not

Table 1. Life assets

Life Assets	X	S.D.	Interpretation
self-power	3.35	.587	moderate
family power	3.56	.610	high
intelligence building	3.00	.552	moderate
friend power and activity	2.82	.746	moderate
community power	3.09	.723	moderate
Total	**3.16**	**.644**	**moderate**

Table 2. Nurture

Nurture	X	S.D.	Interpretation
the caring care model	3.90	.947	high
the control model	2.48	1.027	low
the indulged model	3.00	.899	moderate
the abandoned model	2.09	1.036	low
the family relationship model	4.03	.861	high
Total	**3.10**	**.954**	**moderate**

Table 3. One-way Analysis of Variance of Tramadol Abuse Behavior Classified by Age

Source of variance	SS	df	MS	F	P
between groups	27.870	2	13.935	11.988	.000**
within the group	295.251	254	1.162		
Total	**323.121**	**256**			

The order of being a child in their family (p =.042) as shown in Table 4

Table 4. One-way Analysis of Variance of Tramadol Abuse Behavior Classified by order of being a child

Source of variance	SS	df	MS	F	P
between groups	10.283	3	3.428	2.772	.042*
within the group	312.838	253	1.237		
Total	**323.121**	**256**			

Behavior of using drug substances (p =.041) as shown in Table 5,

Table 5. Difference with the T-test of controlled substance abuse behaviors and the misuse of the dangerous drug tramadol

Controlled substance abuse Behaviors	N	X	S.D.	t	p
use	218	2.89	1.124	2.051	.041*
don't use	39	2.49	1.073		

The channels for purchasing Tramadol (p =.014) as shown in Table 6,

Table 6. Difference with the T-test of channels for purchasing Tramadol and the misuse of the dangerous drug tramadol

Channels for purchasing Tramadol	N	X	S.D.	t	p
yes	17	2.18	.951	-2.487	.014*
no	240	2.87	1.122		

The selection of ingredients for tramadol use (p =.000) as shown in Table 7,

Table 7. One-way Analysis of Variance of Tramadol Abuse Behavior Classified by ingredients selected for tramadol use

Source of variance	SS	df	MS	F	P
between groups	103.135	4	25.784	29.536	.000**
within the group	219.985	252	.873		
Total	323.121	256			

The family relationship (p =.039) as shown in Table 8.

Table 8. One-way Analysis of Variance of Tramadol Abuse Behavior Classified by family relationship

Source of variance	SS	df	MS	F	P
between groups	10.470	3	3.490	2.824	.039*
within the group	312.651	253	1.236		
Total	323.121	256			

The family relationship (p =.039) as shown in Table 8.

use other ingredients) more frequently misuses dangerous drugs like tramadol than the sample selected to drink mixed with beverages.

The sample selected for mixing with drinks and taking whole tablets/capsules (which do not use other ingredients) tended to misuse the dangerous drug tramadol more than the sample who took the pill/capsule. (Do not use other ingredients).

The sample selected all 3 types of drugs, namely: 1) mixed with beverages, 2) ingesting whole tablets or capsules (no other ingredients should be used), and 3) mixed with drugs. The behavior of taking tramadol in the wrong way was more than that of the sample that chose to mix it with beverages such as tea, coffee, or soft drinks. energy drinks, liquid cough medicine, etc. The sample selected 3 types of drugs, namely: 1) mixed with a drink, 2) ingesting whole tablets or capsules (no other ingredients), and 3) in combination with drugs. The behavior of taking the dangerous drug tramadol in the wrong way was more than the sample who took the pill or capsule. (Do not use other ingredients).

In terms of family relationships that differed statistically at the 0.05 level, there was 1 pair, i.e., the sample had family relationships at a high level. They had more misuse of the dangerous drug tramadol than the sample with family relationships at the highest level.

12. Discussion

The study found that 257 children and adolescents who were addicted to tramadol for the first time started taking tramadol at an average age of 15 years, and the youngest age was 10 years old, which is the initial stage in entering adolescence that is at risk of being persuaded or suggesting appropriate behavior or committing offenses more easily than other ages because they still lack good skills in life and want to try and take risks, in line with the concept of criminology, life-course theory. [13]. It is considered the most problematic age range compared to other groups and is the period with the highest number of offenses, especially among those aged 13–18.

Children and young people take tramadol in two forms: tablet or capsule and mixed with other ingredients. The main ingredients are carbonated soft drinks and liquid cough syrup, but there may be other ingredients depending on personal preference, such as Kratom 4 x 100, energy drinks, alcoholic beverages, beverages containing instant caffeine, etc. This is consistent with the data of the National Statistical Office [14], which found that " children and adolescents use various substances which are easy-to-find and mixed to act like narcotics, and they are tried because they think that it is a mixture of harmless substances regardless of its narcotic effect." From the results of the study, it was found that most of them were commonly mixed with soft drinks. Of the 202 subjects, 78.6% had the habit of taking tramadol with a minimum of 1 tablet/capsule/time and a maximum of 160 capsules/time. Children and adolescents are at a growing age. They are inquisitive, imitative, and expressive; have a strong temper; little restraint; are weak and inexperienced; and are easily misled by others. This was in line with the theory of G. Stanley Hall, who is regarded as the father of adolescent psychology. He said adolescence is the age of storms and stress. [15] In a bad environment, these children and young people are more prone to deviant behavior and lead to wrongdoing, that is, behavior that deviates from the norms of society.

Therefore, if children and young people are habitually addicted to tramadol in large quantities and continue to use it regularly, it can lead to addiction. This is because tramadol has similar effects to morphine, which is a narcotic. It affects the development of the body, mind, and nervous system, or brain. Particularly in children and adolescents, at the critical stage of life, they experience rapid changes in their physical, mental, emotional, social, and intellectual development, facing new self-realization. It is a critical stage of life, so adaptation should be of high quality. Moreover, they must be protected and developed following the rights of the Convention on the Rights of the Child, to which Thailand is a party, and the Child Protection Act 2003, because children and adolescents are a vital force for the nation in the future. The group at risk of using Tramadol is mostly informal school students rather than formal school students because informal school students are more likely to use other drugs such as amphetamine, methamphetamine, ketamine (Ketalar), etc. [16]

Tramadol's distribution channel is mostly from friends, seniors, or juniors, amounting to 207 people, representing 80.5%, because friends are very important to children and adolescent's society. Teenagers tend to be more trusting and intimate with their peers than their parents or family members. This is in line with the research by Tippa Chetchaowalit [17], which found that friends will become a new group of children and adolescents who are more closely connected because they spend more time at school than their family at home and are of the same age. For teenagers, friends become a whole new world where they talk, mourn, and express their feelings, dreams, and needs. It is a world that most people like and understand. Children and adolescents, therefore, focus primarily on building their identity among friends and consider acceptance from their friends important, so children and adolescents are easily influenced by their peers in their generation to lead them in the wrong direction. This is consistent with SuriyadewTrepati's concept of life assets [18], who said, "Friends are very important to teenagers. If teenagers have good friends, it will increase the cost of living well. But if they have friends in the risk group who lead them to do bad activities, it

will result in problems in life. ”

The results of the study found that nowadays, buying and selling tramadol through social media is the most concerning issue because there are many private parcel delivery businesses and there are no strict checks, making it possible for children and young people to easily buy and consume tramadol. This is consistent with the study by WarangkanaChankong and PajareePhonprasert [19] on guidelines for immunization and drug prevention among children and adolescents outside the school in Kamphaeng Phet Province. It was found that ”easy access to online media is an external factor that drives children and young people to drug addiction,” as children and young people are Generation Z populations. Most of them use text-based communication on a mobile phone or computer screen instead of talking.

Plus, smartphones have become the 33rd organ of Gen Z according to the Generation Z feature classification. [20] These people are the demographic that was born and grew up with the advancement of technology, making it easier and faster to learn and access information based on their interests. Therefore, the reason for the increase in the arrests of illegal manufacturers and smugglers of tramadol is that it follows a marketing mechanism when the demand for those who bring tramadol to market is increasing. As a result, the production, market for sale, and illegal sale of tramadol for profit have also increased.

In terms of knowledge, the results of data collection of 257 children and adolescents who had used Tramadol in the wrong way found that 115 people in the sample received a score of knowledge about the dangers of Tramadol use in the wrong way, not more than half, representing 45.8%. Of those, 133 people had a moderate level of knowledge of legal measures to control tramadol, representing 51.8%. The importance of educating children on the dangers of drug misuse and legal measures for the control of dangerous drugs for children and young people is consistent with the Convention on the Rights of the Child on Social Welfare Principles for Children to protect children and adolescents and to provide children and adolescents with information that is beneficial to the development of health care, proper behavior, and prevention of problems for children and adolescents from misusing Tramadol. It is also in line with the Child Protection Act 2003, which is a law that protects the welfare, development, and rehabilitation of children, with a child’s best interests in mind.

13. Conclusion and Recommendation

The study reveals that there is growing abuse of tramadol in Thailand. Tramadol is very common among children and teenagers. They mixed Tramadol with coffee, Kratom juice, soft drinks, energy drinks, or alcoholic drinks to mimic the effects of narcotic substances. As a result, a quiet hazard that is becoming a concern in Thai society is a surge in harmful drug usage among children and adolescents, leaving them unable to control their desires for narcotic substances. Particularly concerning is the mental health of drug addicts who need to take drugs all the time and require more. But this is the result of only one piece of research. More research is necessary to truly understand the impact of tramadol on Thai youth.

Based on the findings, the researchers would recommend the Thai government should have policies in place to prevent dangerous drug abuse of children and adolescents by strengthening the life assets of children and adolescents, which include self-power, family power, intellectual power, peer power and activity, and community power, as well as the designation of safe areas for children and adolescents that facilitate the psychological, social, and intellectual development of children and young people to be able to grow up in a society with quality, with appropriate behavior, and be an important force in the country’s further development.

The Drug Act 1967 should be amended so that it can be enforced in practice by increasing the rate of punishment for those who violate the law under the Drug Act 1967 following the current economic and social conditions of Thailand and increasing strict control measures on illegal drug distribution channels, especially the buying and selling channels through social media, which are the channels used by teenagers utilizing parcel delivery by post or private There must be a process that can check the items and the list of recipient-sender accurately, etc., to prevent illegal parcels from being transported. [21]

All agencies involved in the Drug Act of 1967 should formulate effective strategies and measures for supervision, investigation, and suppression to reduce the supply cycle that makes buying and selling dangerous drugs easy.

The Ministry of Public Health must be the primary source of information about the dangers of drug abuse and related legal measures, delegating authority to agencies such as the province’s public health office, which must be in charge of organizing training or creative activities to educate students and teachers within the school.

The Department of Children and adolescents Affairs must be the primary unit in charge of strengthening the lives of children and adolescents of all ages by defining a strategic framework in five areas, namely: self-power, family power, intellectual power, peer power and activity, and community power, as well as developing an annual operational plan, identifying clear project plans and activities, and setting indicators for monitoring and evaluating the opera’s success.

Family institutions must evolve to meet the needs of Generation Z populations that were born and raised in a technologically advanced era. Parents and guardians

must closely observe, monitor, and monitor their children's behavior, especially their access to social media because it is a medium that has a great influence on children and adolescents, as well as learn to understand children and adolescents in this era by using reasoning in cultivating and guiding them to be aware of the problems and effects of dangerous drug use.

14. Limitation of Research

The sample was only those children and adolescents who are under the control of the Regional Juvenile Vocational Training Center (RJVCT) 1-11 and were willing to provide information voluntarily. In fact, there are a lot of young people in the educational system who misuse tramadol, but they do not want to draw attention to themselves. Thus, there was a limit to accessing a lot of samples.

Conflict of Interest The author(s) declare(s) that there is no conflict of interest.

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Digital Logic Gate Simulation in Computer and IT for Agricultural Communications Course

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Abstract

The Computer and Information Technology (IT) for Agricultural Communications Course requires students to learn about computers and electronic devices. The course includes instruction on logic gates. This study proposes a hands-on operational design using the WeMos D1 R2 microcontroller as a research facility for experiments in the basic logic gate laboratory. The results of the experiment show that the system can be used because the results obtained are based on theoretical results. The electronic circuit's components were replaced by the WeMos D1 R2 microcontroller. It is simple to use and adaptable, demonstrating the operation of logic gates and Boolean algebras. This practice is also an innovative teaching of logic gates and Boolean algebra that has been demonstrated for a clearer and better understanding.

Keywords: Digital Logic Gate, Simulation, WeMos D1 R2

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1. Introduction

Logic gates are the building blocks in logic design. The fundamental gates are used in a sequential and appropriate manner to develop sequential and combinational circuits to solve complex problems. The understanding of basic gates functionality through simulation using LEDs and switches controlled by Arduino represents a strong learning aid. Teaching and learning mechanisms are presently transforming into new dimensions by making use of the latest state-of-the-art technologies to present information in an easy and lucid manner to the learner [1].

Amazingly, computers, digital calculators, and devices that can work for humans are all made up of digital devices and circuits that work logically, and digital circuits have the basic component of logic gates. Because logic gates operate in the same way as binary number systems (with 0 and 1), people who work with electronic digital systems must understand and use them correctly. This research will investigate the functions of basic logic gates such as AND, OR, NOT, NOR, and NAND as the foundation for building more complex logic circuits [2]. Digitalization technology plays a role in the operation of electronically controlled devices allowing more efficient development and ability to work quickly with complex systems. The design can be created cheaply, easily, and quickly, which is the problem with having to create digital circuit learning materials, because learning digital circuits in general does not yield immediate results. It's difficult to comprehend. As a result, the researchers concluded that creating a Digital Logic Gate using the WeMos D1 R2 microcontroller for teaching can be used as a learning medium for digital design that students can use effectively and improve their understanding. It simulates digital circuit operation on the WeMos D1 R2 microcontroller, which simulates a logic gate AND, OR, and NOT gates.

The WeMos D1 R2 can connect to a 2.4 GHz Wi-Fi network, connect both boards via a USB cable, and the WeMos D1 R2 adapter can be connected via an additional voltage regulator, and the power from the 9-12 volt adapter can be powered by a 9-12 volt adapter [3]. The Computer and Information Technology for Agricultural Communications course is taught to first-year Agricultural Leadership and Communications students at the Faculty of Animal Science and Agricultural Technology, Silpakorn University. All students must take this course, which includes the implementation of a low-cost WeMos D1 R2, which costs only 3 USD. In addition to learning about microcontrollers, electronics is also essential for understanding the WeMos D1 R2 device. It is used in the field of things and others related to smart agriculture, which is why this research is being conducted.

We understand that students in the agricultural communications course need to learn about digital circuits, so we created a learning resource to help them under-

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stand better. We use WeMos D1 R2 microcontroller in this study to build a foundational learning unit that allows students to experiment with basic digital logic circuits. We recognize the importance of using technology in teaching and learning by connecting WeMos D1 R2 microcontroller with the study of digital circuits and Boolean algebra. It improves students' understanding and effectiveness in teaching digital logic circuits and Boolean algebra, allowing them to tackle more complex problem-solving tasks. Experimenting with WeMos D1 R2 microcontroller-based digital logic circuits, for example, can help students understand the practical application of logical principles and Boolean algebra in real-life scenarios. We establish a link between experiments and the learning outcomes that students can derive from using this technology in their coursework by constructing digital logic circuits that operate in real-world situations using the cost-effective WeMos D1 R2 microcontroller. As a result, expanding on the problems and rationale for this research demonstrates its importance in improving teaching and learning in the Computer and Information Technology for Agricultural Communications Course.

2. Implementation of WEMOS D1 R2 Logic Gates

WeMos D1 R2 is a board that uses ESP8266 WIFI to create a format similar to the Arduino UNO R3, making it easier for users to connect. Or it's the ESP8266 WIFI in the Arduino UNO draft. Connect via USB with TTL USB Chip CH340 for uploading programs to the board. We can use the Arduino IDE, but it is necessary to install its USB driver first [4].

WeMos D1 R2, a microcontroller based on the ATmega328p, is low-cost, intelligent, and flexible, and is used to develop small circuits by connecting sensor devices to WeMos D1 R2 via digital and analog input/output pins [5]. The sketch can be uploaded to the microcontroller by the programmer using the Arduino IDE software [6]. An image of WeMos D1 R2 board is shown in Figure 1.

3. Logic constants and logic variables

Operation in digital format It is explained using algebraic logic equations with logic variables. It is a variable that only accepts two values, also known as a two-state variable, because only two states can exist and will be in either state. Being located in both states at the same time does not represent various meanings such as on-off, high-low, one-zero, and so on [7].

Algebraic logic It is used to discover facts about logical actions that are distinct from algebraic. In general, logical algebra is made up of constants, and only two variables, 0 and 1, are called logic variables and can be represented by letters like A, B, C, a, b, c,... etc.

The logic level is the value of a logic variable that has a value of 0 or 1 at different times. We can replace it with a logic level, such as a voltage level ranging from 2 to 5 volts, with a logic 1 value, so that the voltage value in a digital circuit has a logical level of 0 or 1, depending on the actual value of the circuit operation.

4. The circuit diagram

4.1 Circuit Diagram Description:

In this example, we'll build a circuit with a WeMos D1 R2 microcontroller to simulate an AND gate using LEDs and switches. This basic circuit will assist students in comprehending the operation of logic gates.

4.2 Components Needed:

4.2.1 WeMos D1 R2 microcontroller
4.2.2 Two touch-press switches (SA and SB)
4.2.3 Two LEDs (green for switches A and B)
4.2.4 Two 220-ohm resistors
4.2.5 Jumper wires

4.3 Circuit Connections:

4.3.1 Connect SA (switch A) to digital pin D1 on the WeMos D1 R2.

4.3.2 Connect SB (switch B) to digital pin D2 on the WeMos D1 R2.

4.3.3 Connect the green LED for switch A with a 220-ohm resistor in series to digital pin D3 on the WeMos D1 R2.

4.3.4 Connect the green LED for switch B with a 220-ohm resistor in series to digital pin D4 on the WeMos D1 R2.

4.3.5 Connect a red LED to digital pin D0 (D3) on the WeMos D1 R2. This LED will represent the output Z of the AND gate.

4.4 Circuit Operation:

4.4.1 When both switches SA and SB are in the OFF position (0), the green LEDs for switches A and B will remain OFF.

4.4.2 When either switch SA or SB is turned ON (1), the respective green LED will turn ON.

4.4.3 When both switches SA and SB are turned ON (1), both green LEDs will be ON.

4.4.4 The red LED connected to digital pin D0 (D3) will act as the output Z of the AND gate. It will only turn ON when both switch A and switch B are ON (1).

This simple circuit allows students to experiment with an AND gate's behavior using the WeMos D1 R2 microcontroller. It visually demonstrates how logic gates operate by controlling LEDs based on the input switches' positions.

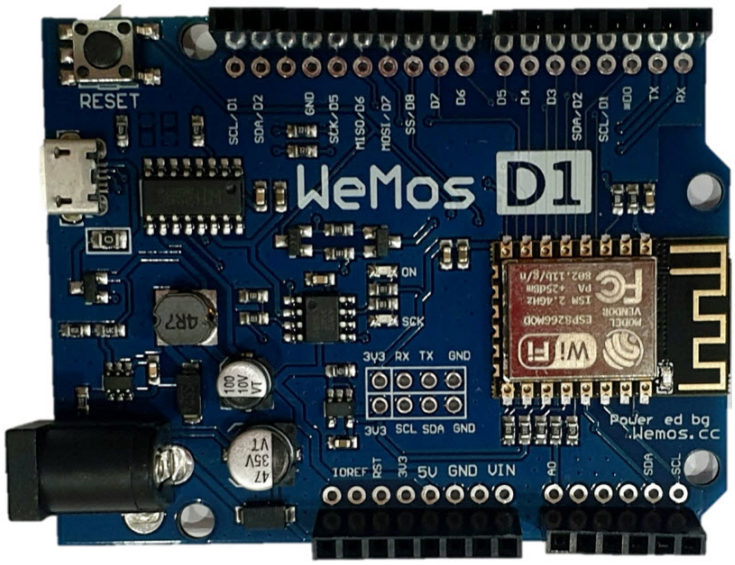

Figure 1: WeMos D1 R2 board.

5. Teaching instruction sheet design

In this section, we will look at the design of the teaching instruction sheet, which is an essential component of our educational approach. The teaching instruction sheet is an essential tool for learning and experimenting with digital logic circuits using WeMos D1 R2 microcontroller.

Our goal is to provide students with a well-organized and user-friendly resource that will help them better understand digital logic gates and their applications. The following key elements have been incorporated into the design of the teaching instruction sheet:

5.1 Title and Objective: The teaching instruction sheet starts with a clear and concise title that summarizes the subject of study. It also includes a brief statement of the learning objectives, emphasizing what students should gain from the activity.

5.2 Components List: We provide a detailed list of the components needed for the experiment. WeMos D1 R2 microcontroller, USB cable, touch switches, resistors, LEDs, and jumpers are all included. For easy identification, each component is accompanied by a brief description.

5.3 Circuit Diagram:A detailed circuit diagram is included to show how the components are connected. We emphasize the importance of understanding the circuit layout and how each element contributes to the logic gates' functionality.

5.4 Step-by-Step Instructions: The teaching instruction sheet's heart is made up of step-by-step instructions for setting up the experiment. We break the process down into manageable stages so that students can follow along without getting lost. To aid comprehension, each step is accompanied by clear explanations.

5.5 Logic Gates Exploration: We encourage students to use WeMos D1 R2 microcontroller to investigate the behavior of basic logic gates such as AND, OR, and NOT gates. The instructions walk them through different input scenarios and show the corresponding output results.

5.6 Discussion Points: We incorporate discussion points and questions throughout the teaching instruction sheet to actively engage students in the learning process. These questions encourage students to think critically and reflect on the results they have observed.

5.7 Troubleshooting Tips: Recognizing that experimentation can be difficult at times, we have included a section with troubleshooting tips. This gives students advice on how to deal with common problems that may arise during the experiment.

5.8 Learning Outcomes: We conclude the teaching instruction sheet by summarizing the experiment's key learning outcomes. This reinforces the educational objectives and allows students to assess their understanding.

Overall, the goal of our teaching instruction sheet design is to encourage students to actively participate in hands-on learning experiences, resulting in a better understanding of digital logic gates and their practical applications. It is consistent with contemporary educational approaches that use technology to enhance the learning process and make complex concepts more accessible to students. We emphasize the importance of this instructional resource in improving teaching and learning in the Computer and Information Technology for Agricultural Communications Course by linking it to our research.

6. The Application and Results

This section delves into the practical application of WeMos D1 R2 microcontroller-based digital logic gate experiments, as well as the outcomes of these educational endeavors. Our goal was to help students understand the practical implications of digital logic gates and Boolean algebra by bridging the gap between theoretical knowledge and real-world application.

6.1 Practical Application of WeMos D1 R2

WeMos D1 R2 microcontroller was an invaluable tool in demonstrating the usefulness of digital logic gates. This versatile microcontroller, outfitted with ESP8266 WIFI capabilities, enabled us to create an environment that was very similar to the Arduino UNO R3, facilitating ease of use and connectivity. Although it required the installation of a USB driver, its compatibility with the Arduino IDE streamlined the programming process [4].

WeMos D1 R2 microcontroller was instrumental in introducing students to the world of microcontrollers and electronics in the context of the Computer and Information Technology for Agricultural Communications Course. While the primary focus was on digital circuits, students also learned about the functionality of WeMos D1 R2 device. Given the device's importance in smart agriculture and the Internet of Things (IoT), this comprehensive approach was critical.

6.2 Educational Outcomes and Results

In terms of educational outcomes, our digital logic gate experiments produced significant results. Students were able to understand theoretical concepts as well as witness their practical implementation by using the WeMos D1 R2 microcontroller. The following are the key findings and outcomes of the experiments:

6.2.1 Enhanced Understanding: Hands-on experiments with WeMos D1 R2 microcontroller improved students' understanding of basic logic gates such as AND, OR, and NOT gates significantly. They could see how these gates worked in real time and how input changes affected the output.

6.2.2 Application of Boolean Algebra: Students were able to design and understand digital logic circuits using Boolean algebra principles. This practical application bridged the knowledge gap between theory and practice.

6.2.3 Problem-Solving Skills: Experimenting with digital logic circuits based on WeMos D1 R2 microcontroller provided students with problem-solving skills. They could troubleshoot and debug circuit problems, developing critical thinking skills.

6.2.4 Relevance to Smart Agriculture: Students recognized the real-world relevance of their learning because WeMos D1 R2 microcontroller has applications in smart agriculture. They could see how their new skills could be applied in agricultural settings, which aligned with the course objectives.

6.2.5 Linking Experiments to Learning Outcomes: We established a clear link between the experiments and the course learning outcomes. Students were able to see how the practical application of logical principles and Boolean algebra helped them achieve specific educational objectives.

Finally, the digital logic gate experiments using WeMos D1 R2 microcontroller proved to be a valuable educational tool. They not only improved students' understanding of digital circuits, but they also provided them with practical skills that can be applied in a variety of fields, including agriculture. We ensured that the educational outcomes were met effectively by aligning the experiments with the course's learning objectives. These findings highlight the significance of incorporating innovative teaching methods and technology to promote a deeper and more comprehensive understanding of complex subjects.

The study was carried out experimentally in electrical and electronic laboratories, simulating logic gates. For logic simulation, the gate simulation to demonstrate the mechanisms of three basic logic gates is AND, OR, and NOT gates. Simulation with WeMos D1 R2 requires the following: A USB cable, 2 touch switches, 220 ohm resistors, 3 LEDs, and jumpers. Figure 2: Actual circuit construction for a logic gate experiment

To make the circuit work, the code was developed using the C language and the Arduino IDE. The circuit consists of two touch-press switches as switch inputs, SA and SB; two LEDs as inputs, green for switches A and B, respectively; and red LEDs as Z outputs. When the LED is turned on, the binary number '1' is recorded, and when the LED is turned off, the binary number '0' is recorded, and the output LED lights turn on according to the operation of the LED. The output Z is put on pin 0 (D3) GPIO: General Purpose Input/Output of Wemos D1 R2. The Arduino IDE code for AND, OR, and NOT gates is as shown below in Figure 3, Figure 4, and Figure 5, respectively. Tables 1–2 show the results of each logic gate.

Input logic circuit simulation defined as LED A and B defines LED output Z, with output Z open or closed according to the truth table of basic logic gates, namely, AND, OR, and NOT gate. As a key component of this research, these are basic circuits that will amplify the complex work results that benefit students in laboratory activities.

7. Conclusion

Finally, this study provided invaluable insight into the effective integration of WeMos D1 R2 microcontroller as an educational tool for teaching digital logic gates. Our findings show that students' understanding of fundamental logic gates, their practical appli-

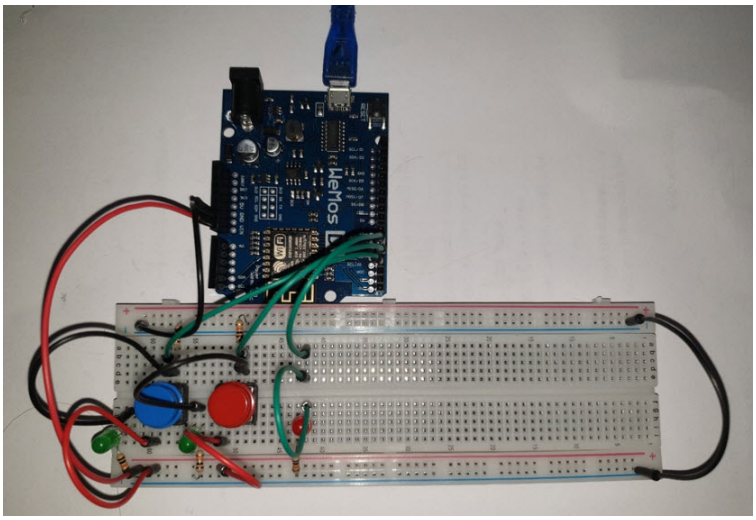

Figure 2: Actual circuit construction for a logic gate experiment.

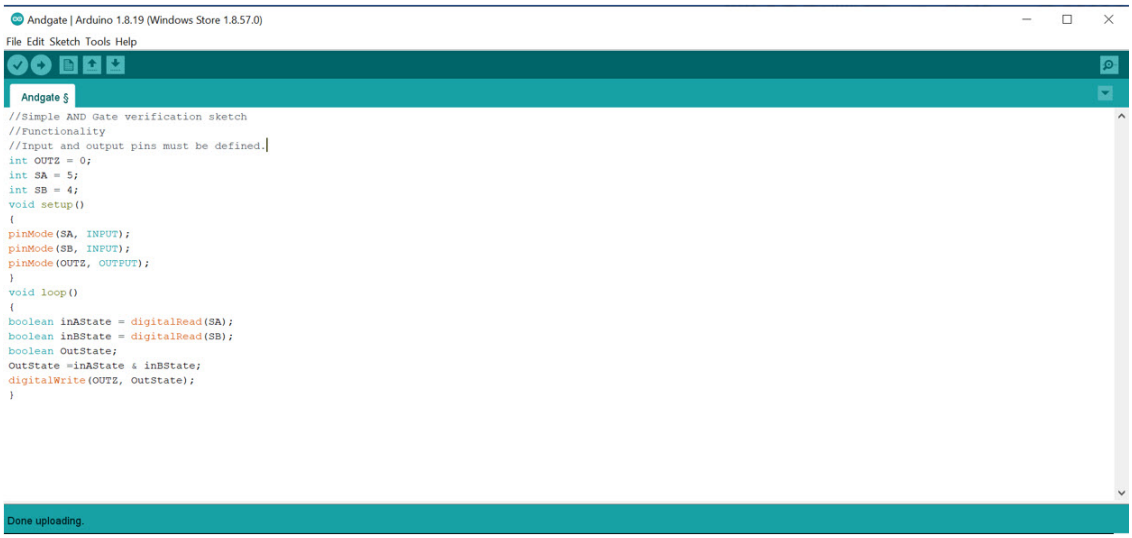

Figure 3: Shows an AND gate's Arduino code.

Table 1. AND gate results

Input logic		Logic Output Z	
SA	**SB**	**Theoretical**	**Experimental**
0	0	0	0
0	1	0	0
1	0	0	0
1	1	1	1

Table 2. OR gate results

Input logic		Logic Output Z	
SA	**SB**	**Theoretical**	**Experimental**
0	0	0	0
0	1	1	1
1	0	1	1
1	1	1	1

Table 3. Not gate results

Input logic	Logic Output Z	
SA	**Theoretical**	**Experimental**
0	1	1
1	0	0

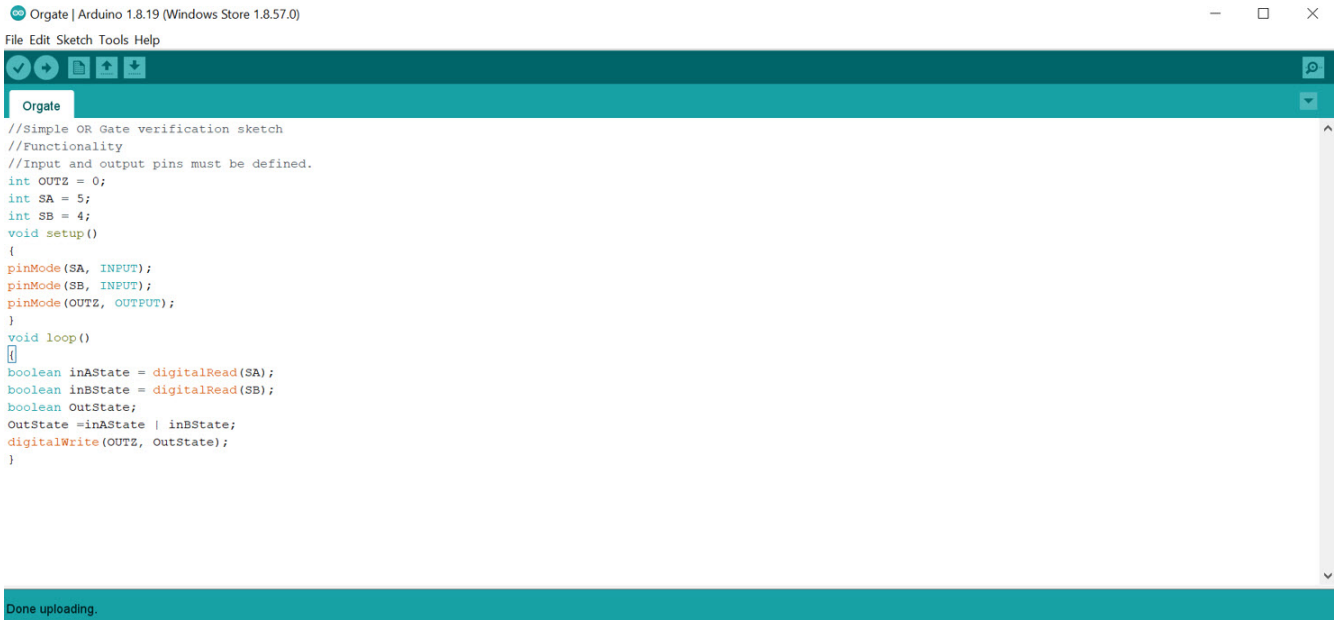

Figure 4: Shows the Arduino code for the OR gate.

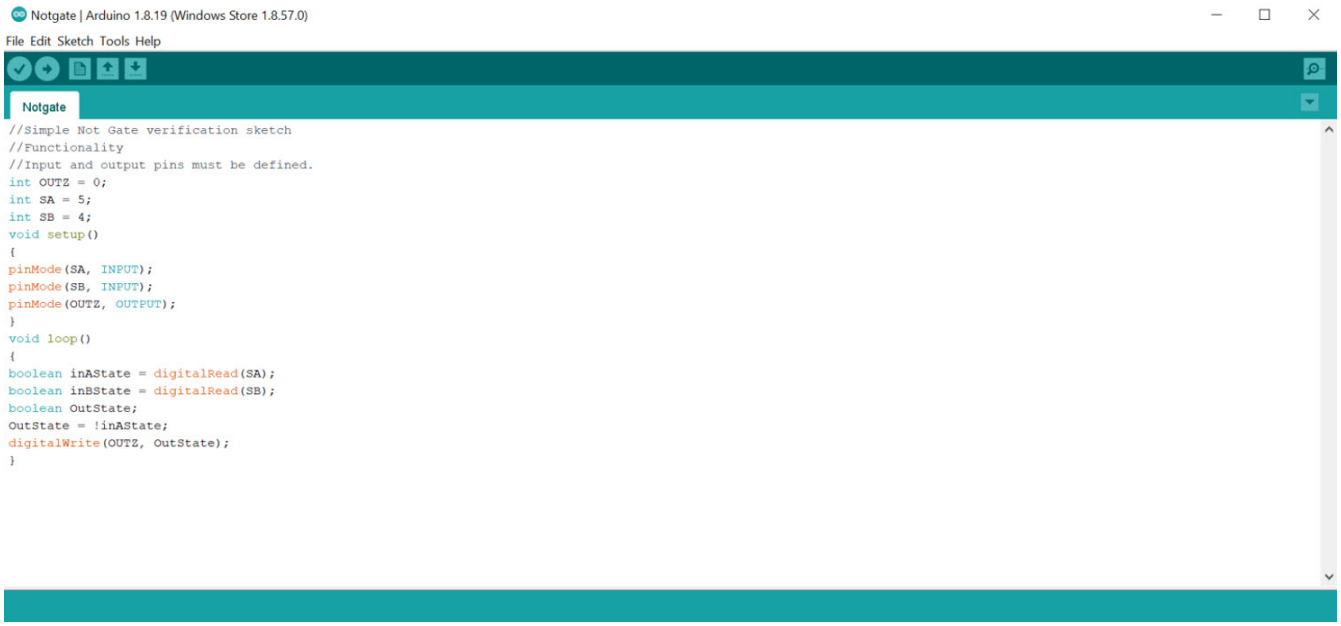

Figure 5: Shows the Arduino code for the Not gate.

cations, and the bridging of the gap between theory and real-world relevance in smart agriculture have improved significantly.

Students not only gained a better understanding of digital circuits through hands-on experiments and simulations, but they also developed critical problem-solving skills. These newfound abilities enable them to effectively address complex challenges in the field of agricultural communications.

The versatility and low cost of WeMos D1 R2 microcontroller make it a valuable asset in the educational landscape, providing students with a tangible platform to explore digital logic principles. Furthermore, our instructional approach is consistent with current educational trends that use technology to make complex concepts more accessible and engaging.

Overall, the successful implementation of WeMos D1 R2 microcontroller in teaching not only improved students' learning experiences, but also demonstrated its potential as a transformative tool in fostering a deeper understanding of digital logic gates and their real-world applications. We believe that this research will make a significant contribution to the advancement of innovative teaching methods and the integration of technology in education.

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