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Promoting Alternatives to Harmful Pesticides on Small Farms

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Promoting Alternatives to Harmful Pesticides on Small Farms

An Interactive Qualifying Project Report submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science in cooperation with Chulalongkorn University

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Abstract

Tomatoes are an important cash crop in the Tao Ngoi District that are vulnerable to diseases, pests, and fungi. Pesticides are an affordable and easy pest management solution that increase crop yield and quality but have negative effects on farmer health and local ecosystems. Alternative farming methods such as organic fertilizers, Good Agricultural Practice, and Effective Microorganisms reduce the need for pesticides but not all farmers in the area practice these methods. Our team sought to understand the limitations of adopting organic methods and to identify the most feasible alternatives. We piloted a program for students at the Tao Ngoi Pattanasuksa School that demonstrated the benefits of mulch, EM technology, and crop rotation and provided recommendations to help farmers decrease their pesticide use.

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Executive Summary

Introduction

Agriculture is an important sector for Thailand's economy because it provides jobs to many people and accounts for a large portion of the country's exports. Sakon Nakhon is a province in northeast Thailand made up of farmland. Sakon Nakhon is beneficial to Thailand's agriculture sector as its geography allows the province to produce a wide variety of crops. Tomatoes are one crop grown in Sakon Nakhon that can sell for a high price, making them financially advantageous to produce. The Tao Ngoi district within Sakon Nakhon is especially involved in the production of tomato plants, and is often referred to as the "Tomato Belt" of Thailand. A wide range of diseases and pests caused damage and tarnishment to tomato plants, making tomato plants difficult to grow Buyers demand that the tomatoes are visually appealing and large, so farmers combat the harmful agents that affect the tomatoes with synthetic pesticides and fertilizers. In the short term, pesticides allow farmers to produce larger and attractive fruit that will sell for a good price, but in the long term, the use of pesticides has negative effects.

The overuse of harmful chemicals found in pesticides can cause a variety of health and environmental issues. Pesticide Residue that is present on crops and in bodies of water near farms is harmful to consumers and to local ecosystems. Pesticides can also kill the beneficial microorganisms found in the soil, and over time, the soil degrades and loses its ability to hold important nutrients needed to grow plants. Alternative farming methods such as Effective Microorganism technologies, organic mulch and fertilizers, and crop rotation are all techniques that can help lessen the harmful agents that affect tomato plants while reducing the need for pesticides.

Our project sponsor, the Tao Ngoi Pattanasuksa School, recognizes that teaching students about organic farming practices may spark community interest and will aid in educating current and future farmers. Our project goal was to design a program that would teach students at the Tao Ngoi Pattanasuksa School about the effects of overusing pesticides and encourage the switch to sustainable farming methods. Our team accomplished this by visiting Sakon Nakhon to interview farmers, the Ministry of Agriculture, students, and teachers at the Tao Ngoi Pattanasuksa School, as well as experts at the Science Center for Education, and experts on plant diseases and microorganisms from Chulalongkorn University. We created a program for the students using the information from these interviews and piloted it at the school. We revised our program and wrote recommendations for the school to help them continue the program in the future. Lastly, we wrote recommendations for the farmers to assist them in switching to the most effective organic farming methods.

Methodology

To achieve the project goal, our team interviewed farmers and employees at the Ministry of Agriculture in Tao Ngoi to fully grasp the issues surrounding pesticide use and the limitations of adopting other farming techniques. We gathered information from The Golden Jubilee Museum of Agriculture to determine feasible organic farming methods to mitigate the problems we saw on the farms. From the analysis of this information, we chose three main learning objectives for our program and established possible solutions to the issues surrounding tomato farming.

We talked with students and teachers at the Tao Ngoi Pattanasuksa School to learn about previous agricultural programs held at the school: why they failed, what was successful, and where improvements they could make. This information allowed us to tailor our program design for maximum success. To engage students in our program our team needed to utilize effective educational techniques. Conversations with Tao Ngoi Pattanasuksa students were instrumental in developing an appealing program. We designed our activities based on overall student interests and suggestions made by experts at the Science Center for Education who have experience in creating activities for students.

Our team designed a program using the information gained in the interviews and piloted it for eighth graders at the Tao Ngoi Pattanasuksa School. We gathered feedback on the program from surveys and made revisions to improve its effectiveness. Our team developed recommendations for the school including maintaining the program's continuity in the future and involving student clubs to increase participation. We also established recommendations for the Tao Ngoi Ministry of Agriculture to improve data collection on pesticide use and to make organic farming workshops more accessible to farmers. Our recommendations also include organic farming techniques we found to be the most effective and realistic for Tao Ngoi farmers.

Results and Analysis

Our team analyzed data obtained from interviews and site visits. We found that most farmers use organic farming techniques and pesticides. However, farmers use pesticides as a last resort to combat yellow and green wilt disease as well as pests and fungi that harm the tomatoes. We also found that some farmers went to workshops on farming to learn about other methods that were not as harmful as pesticides. We spoke to one farmer who became 100% organic. The pesticides he used caused skin irritations, so he attended a workshop hosted by a chemist to learn about organic farming methods. Among other methods, he learned how to use beneficial microorganisms, also called Effective Microorganism technology (EM Technology), to grow and protect crops. After using these new methods, his tomatoes were large and visually appealing.

We also learned about techniques for educating students. We discovered that activities that include prizes and are shorter, interactive, and competitive are the most successful for our target participants. Finally, we created and piloted a program at the Tao Ngoi Pattanasuksa School. The program included activities intended to teach about topics such as mulch, fermented juices, crop rotation, EM technology, and tomato diseases.

We administered a short quiz the day before the program to determine what students know about the topics we chose to teach. We administered the same quiz immediately after the program to see how well students understood and engaged with the information. We found that students scored significantly better on the survey after participating in the program. This indicates that our program was successful at introducing and explaining the information to the students. The program did have some limitations such as the students not having internet access, some of the microscopes not working properly, and difficulty with students making their own slides from the EM technology. Our team revised the program based on these findings and developed instructions for Kru Suchaya and the agricultural club so the Tao Ngoi Pattanasuksa School could continue to run this program as part of its curriculum in the future.

Recommendations and Conclusion

After piloting the program to the Tao Ngoi Pattanashcksa School, our team developed revisions and wrote instructions for the activities.

- The information from this educational program benefited the students as it taught them about organic farming methods such as EM technology, fermented juice, and tomato diseases. Therefore, we recommend the Tao Ngoi Pattanasuksa School run this program every year with the help of the agricultural club using the instructions provided in Appendix M.

- We recommend Kru Suchaya rename the agricultural club to appeal to students and increase attendance.

- We recommend The Tao Ngoi Ministry of Agriculture develop a database with information on pesticide usage in Sakon Nakhon. Having a database with this information would help the district regulate the types and amount of pesticides used.

- We recommend the district encourage farmers to attend workshops and create a schedule of workshops for farmers to attend to learn about organic ingredients and methods. After interviewing farmers in the district of Tao Ngoi, we learned that some of them attended workshops to learn about farming methods and topics related to organic techniques. If more farmers had access to these workshops, they could learn about organic farming methods such as EM technology and fermented juices to reduce the amount of pesticides used on their farms. Having a schedule could help promote participation in workshops as well as push for the existence of more workshops.

- We recommend Doi Kham provide financial incentives for farmers to switch to organic farming methods.

1. Introduction

In Thailand, agriculture is the backbone of the country. Much of the population works in the agricultural sector, which accounts for approximately 9% of the country's Gross Domestic Product (The World Bank, 2017). To increase productivity, farmers turn to pesticides as an easy means to increase the short-term yield of many crops by protecting them from harmful insects and fungi (Tapanapunnitikul & Prasunpangsri, 2014).

Sakon Nakhon is a province in northeast Thailand largely made up of farmland. This province is heavily involved in and very beneficial for Thailand's agricultural sector. Its geography and access to a water supply support a wide variety of crops including rice, fruits, and vegetables. Tomatoes are an important crop grown in Sakon Nakhon because they sell for higher prices than other crops (Tao Ngoi Ministry of Agriculture Staff, Group Interview, 2019, Jan 16). The Tao Ngoi district in Sakon Nakhon is especially involved in tomato production and is known as the "Tomato Belt" of Thailand (Theparat, 2018). Growing tomatoes has improved the well-being of many farmers in this area, however, due to the high demand of tomatoes, they can be a problematic and expensive crop to grow. There are many diseases, insects and fungi associated with tomato production (Tao Ngoi Ministry of Agriculture Faculty, Group Interview, 2019, Jan 16). Farmers make more money from tomatoes that are visually appealing and large, but these harmful insects, fungi, and diseases can damage the plants, hinder sales, and hurt farmers economically (Ngoipathpan, Thairath, Personal Interview, 2019, Jan 16). Farmers often resort to chemicals and pesticides to prevent insects and fungi from affecting their crops. However, the use of these products results in many negative effects.

Use of pesticides in Sakon Nakhon gives rise to a variety of health and environmental concerns because pesticides are toxic to humans and other non-target organisms (Tao Ngoi Pattanasuksa School Teachers, Group Interview, 2019, Jan 17). Pesticide residue is increasingly present on crops and in water bodies, which can be harmful to humans and animals such as birds, fish, and turtles. Additionally, pesticide treatment can reduce the number of beneficial microorganisms in the soil. Over time, soil loses its ability to hold important nutrients that are essential for farming (Aktar, Sengupta, & Chowdhury, 2009). The impairment of soil quality and the destruction of ecosystems can potentially reduce long-term crop yield.

The goal of our project was to develop a program for students to provide information on alternative farming methods to reduce pesticide use and encourage the switch to more sustainable farming methods. We gathered information from farmers about the problems they experience on their farms and while selling their crops. We talked to The Golden Jubilee Museum of Agriculture, and professors of Biology at Chulalongkorn University to learn about tomato diseases, insects, and bacteria and viable organic solutions to these issues on tomato farms. We also interviewed students at the Tao Ngoi Pattanasuksa School on past agricultural activities and any interests they had. Education experts at The Science Center for Education provided examples of past programs they ran, how to interest students, and how to design engaging activities. We analyzed our findings, developed recommendations, and created a program geared towards younger Thai students about organic farming methods and the dangers of pesticides. Focusing on younger Thai students allowed us to reach a larger audience as they said they would relay the information from our program to their parents. Our project sponsor, The Tao Ngoi

Pattanasuksa School, believes that educating students about organic farming methods and the importance of avoiding pesticide reliance has the potential to create a more lasting change.

We accomplished our project goal through these objectives:

1. Obtain information to identify the problem and potential solutions through interviews, focus groups, and onsite observations.
2. Choose learning objectives for the program using the information obtained from interviews, focus groups, and site visits.
3. Pilot a program using effective educational techniques to teach students about organic farming and gather feedback about its success.

Our team successfully piloted a program at the Tao Ngoi Pattanasuksa School. We taught students about crop rotation, Effective Microorganism technology, which is the use of microorganisms to stimulate natural biological functions in the soil and plant, tomato diseases, and harmful effects of pesticides. We gave the students a quiz before and after the program to ensure they understood the program content. Feedback from surveys helped our team make revisions to the program and develop recommendations for both the Tao Ngoi Pattanasuksa School and the Tao Ngoi District. This report details the research and data we collected, the interviews we conducted, and the recommendations we made with the goal of serving the Tao Ngoi community and reducing pesticide usage among farmers.

2. Background and Literature Review

Our project sponsor, the Tao Ngoi Pattanasuksa School, has expressed concerns about the increasing use of pesticides among farmers in the Tao Ngoi District of Sakon Nakhon, Thailand. Thai farmers heavily depend on pesticides to increase crop yield and prevent a reduction in crop yield due to pests and diseases. However, increasing pesticide use results in environmental degradation and health problems among farmers and the local population. In this chapter, we will outline the factors influencing pesticide use among farmers, the consequences of pesticide use on the environment and human health, alternative organic farming techniques that can replace pesticides and effective educational techniques that resulted in successful educational programs in the past.

2.1 Sakon Nakhon

Agriculture is one of the most important sectors to Thailand's economy with a large portion of the population working in the agricultural sector. The population of rural areas in Thailand rely on agriculture as their main source of income. The Sakon Nakhon province, located in northeastern Thailand, is an area heavily involved in the agricultural sector. The province is approximately 9,600 square kilometers including 5,200 square kilometers (54%) of farmland (National Statistical Office of Thailand, 2011). The Phu Phan Mountain range in Sakon Nakhon supports the growth of three different types of crops: field crops, tree crops, and specialty crops. Sakon Nakhon is particularly famous for its tomato production. Most significantly, it is home to the "Tomato Belt" which occupies 48 square kilometers of farmland in the province that grows tomato plants (Theparat C., 2018).

2.1.1 The King's Influence on Sustainable Farming

In 1969, His Majesty King Bhumibol Adulyadej launched the Royal Project Foundation to combat the issues of poverty and deforestation that were affecting the hill tribes of northern Thailand. Poverty and deforestation were results of opium cultivation. The hill tribes occupied an ideal area for growing opium, at over 900 meters above the sea level. Most of the tribespeople lacked official forms of Thai identification, preventing them from receiving government services such as healthcare and education (Maierbrugger A., 2017). With little to no work alternatives, a lack of farming experience with other crops, and optimal opium growing conditions, the hill tribes cultivated opium as their main crop (Tinra P., 2012). A lack of government regulation surrounding opium cultivation led to additional problems; farmers received insufficient financial compensation due to unethical transactions between middlemen and faced severe deforestation due to the destructive slash-and-burn farming techniques associated with opium growth (Rajani B., 1988).

The Royal Project Foundation sought to improve the quality of life of the hill tribes by reducing opium production, promoting sustainable farming practices, preventing the destruction of natural resources such as forests and streams, and conserving the quality of soil (Barrow R., 2016). The late King discouraged waste and overuse of commodities and encouraged a focus on the environmental, economic, and communal impact of farming methods and everyday habits. As a part of the Royal Project Initiatives, King Bhumibol Adulyadej initiated the "Project for Hill Tribes" and Doi Kham Royal Projects to provide a steady income for local farmers and to distribute high-quality food products for consumers. These

projects promoted diverse cultivation of winter fruits and vegetables, such as tomatoes, to solve the problems of opium cultivation (Kiettewet A., 2016).

Since its founding, Doi Kham Food Products expanded from Chiang Mai and currently has factories located in the Mae Chan district of the Chiang Rai province and the Tao Ngoi district of the Sakon Nakhon province (Bangkok Post, 2017). Doi Kham Food Products' main objective is to produce high-quality food that is free from chemical additives, honoring the initial goals of the Royal Project Foundation.

2.1.2 The Tomato Crop

The Tao Ngoi District in Sakon Nakhon is famous for its tomatoes and tomato products. The Royal Project Initiatives introduced tomatoes to Sakon Nakhon in the 1980s as a solution to poverty that farmers experienced (Roongwitoo, 2014). The King suggested growing tomatoes, which was not an abundant crop in Thailand at the time, because of Sakon Nakhon's suitable weather and geographical conditions. Tomato plants benefited the farmers economically as they sell for higher prices than other crops. Today, tomato farms occupy 48 square kilometers of farmland and provide substantial income for Tao Ngoi farmers (Theparat C., 2018).

2.1.3 Challenges with Tomato Production

Although tomato production has improved the wellbeing of many farmers, tomatoes are difficult and expensive to grow. Several pre-harvest factors add to the challenges farmers face during tomato cultivation; poor nutrient levels, soil pH, temperature, and irrigation patterns can negatively affect the appearance of tomatoes and influence a buyer's decision to purchase a farmer's product. Tomatoes are also susceptible to a number of diseases, pests, and fungi as they are a generally weak crop. These issues can negatively affect the appearance of the crop as well as decrease crop yield.

In order to produce a substantial yield, tomatoes require adequate fertilizer to provide sufficient nutrients in the soil. For instance, nitrogen is a vital nutrient for the growth and development of stems and leaves of the tomato plant, but too much nitrogen combined with the neglect of other important nutrients can lead to a plant with small fruit. Without proper knowledge of soil nutrient balances, farmers cannot supply the proper fertilizers, resulting in defective tomatoes. As seen in Figure 1, physical defects such as "catfacing" deter sales, leading the farmers to shoulder the cultivation costs without making any return.

Figure 1. Catfacing defect in tomato in Sakon Nakhon. January 16, 2019

2.2 Pesticides

Synthetic pesticides, or pesticides produced with synthetic chemicals, first emerged in 1939 with the discovery that dichloro-diphenyl-trichloroethane (DDT) was an extremely effective insecticide. There are four main types of pesticides; insecticides, herbicides, fungicides, and rodenticides. Pesticides kill unwanted plants, weeds, insects, and fungi. These organisms can eat, tarnish, or destroy crops. Developing and developed countries use them to increase crop yields, create more appealing food products, and simplify farming methods. Up to 40% of the world's potential crop production is lost annually due to the effects of weeds, pests, and diseases. These crop losses would likely double if existing pesticide uses were abandoned (Sarwar et al., 2015). The benefit of increased crop yield results in lower food costs for consumers and greater profits for farmers. People have become reliant on pesticides to reduce the risk of famine and ensure an abundance of food.

2.2.1 Health Effects

Insecticides in Thailand commonly contain organophosphates (OPs). They are one type of dangerous compound found in pesticides that have negative health effects. Their primary effects include inhibition of some functions in the nervous system and neuropsychological performance. Skin irritations, and respiratory difficulties. Symptoms include pulmonary edema, cyanosis, muscle spasms, muscle weakness, blurred vision, trouble breathing and possibly respiratory failure, which can lead to death. Several research studies documented Thai farmers' reports of these symptoms as well as nausea, vomiting, numbness in their hands and feet, and chest pain. Luckily, most of these symptoms are reversible, but many farmers are unlikely to seek medical attention and many cases go undocumented (Aktar, Sengupta, & Chowdhury, 2009). Pesticide exposure causes worse symptoms in children than adults. OP exposure has an impact on the growth and development of children and results in long-term effects such as various cancers and developmental defects (Parinya P. et. al. 2012, March).

2.2.2 Environmental Effects

The damage caused by pesticides extends further than human health; pesticide use has harmful effects on the local environment and ecology. Pesticides are not only toxic to the pests they target, but to other organisms including birds, fish, beneficial insects, and non-target plants. Additionally, treatment of soil with pesticides can cause levels of beneficial organisms in the soil to decline. After years of pesticide application, the loss of bacteria and fungi cause the soil to lose its ability to hold important nutrients needed for farming and growing crops. Pesticides also run off the fields and poison nearby ecosystems and water sources. They can flow down rivers and streams and affect organisms far from the original sources of pesticide contamination as well as contaminate other farms that use the same water source. The degradation of soil quality and the destruction of the surrounding ecosystem causes farmers to lose arable land and resources and reduces crop yields long term (Aktar, Sengupta, & Chowdhury, 2009).

2.2.3 Pesticide Regulation

Countries have joined together to address the dangers pesticide use. The Stockholm Convention on Persistent Organic Pollutants was an international treaty signed in 2001 with the goal of restricting the use of persistent organic pollutants. Organic refers to crops grown in untreated soil that are not sprayed with substances prior to three years of harvest (McEvoy M. et al., 2012). This treaty resulted in the ban and restriction of 12 chemicals. 183 countries ratified the convention regulations by 2004. The treaty was amended in 2015 to include 14 more chemical pollutants, most of which were used in pesticides. Thailand signed the treaty in 2002.

Currently, the Hazardous Substance Act B.E. 2535 (1992) regulates pesticides in Thailand and set the Hazardous Substances Committee as the legal body for control of pesticides (Panuwet, Siriwong, Prapamontol, Ryan, Fiedler, Robson & Barra, 2013). However, the enforcement of current regulations is weak because Thailand lacks a uniform system solely dedicated to the management of pesticides. This lack of enforcement allows for the excessive use of pesticides among farmers in Thailand (Panuwet, Siriwong, Prapamontol, Ryan, Fiedler, Robson & Barra, 2013). Since 2017, the Public Health Ministry in Thailand has sought to ban agrochemicals such as paraquat, glyphosate, and chlorpyrifos that are dangerous to human health. In 2018, a research team found 102 people in the district of Nong Bua Lamphu diagnosed with necrotizing fasciitis and connected it with high concentrations of paraquat in the area. Six of these people died. A report from February of 2019 stated that Thailand seeks to ban these harmful pesticides, but paraquat, glyphosate, and chlorpyrifos will remain legal in the country for another two years (The Nation, 2019).

2.3 Factors Influencing Pesticide Use

Thailand relies heavily on pesticides to improve crop production, quality, and appearance, which are growing issues in Thailand. The amount spent towards pesticide imports to Thailand rose from 14 billion Thai baht in 2007 to 24 billion Thai baht in 2013 (Tawatsin A., 2015). The use of synthetic pesticides among farmers raises concerns about human health and environmental issues. Understanding the factors that affect farmers' perception of pesticides and their risks is important to developing feasible alternatives to chemicals.

2.3.1 Tomato Diseases and Pests

For farmers in Sakon Nakhon, tomatoes are vulnerable to various bacteria, fungi, and insects. The bacteria and fungi responsible for tomato plant damage are present within the soil. The bacteria causes a disease in the tomato plant known as bacterial wilt, or "green wilt". As shown in Figure 3, the symptoms of this disease include the wilting of the leaves, blocking of the vascular system of the plant at the roots, and the eventual plant cell death. The bacteria infects the tomato plant through its roots and stem. The bacteria can be spread in several ways, but often spreads to new tomato plant hosts through flowing water, insects and farming equipment (Wangsomboondee, Teerada, Personal Interview, 2019, Jan 23).

The fungus is responsible for a disease known as fusarium wilt, or "yellow wilt." This fungus resides within the soil, and infects tomato plants through its roots and stem. As shown in Figure 2, symptoms of this disease include the gradual wilting of plant's leaves starting at the lower, older leaves and progressing to the upper, younger leaves, a transformation of leaf color from green to yellow, and the eventual death of the plant cells. The fungus thrives in hot, arid weather when the soil is low in moisture. Similarly to the bacteria causing green wilt, the fungus is often be spread via water, insects, or farming equipment (Wangsomboondee, Teerada, Personal Interview, 2019, Jan 23).

Figure 2. Yellow Wilt Disease in a tomato plant in Sakon Nakhon. January 16, 2019

Figure 3. Green Wilt Disease in tomato plants in Sakon Nakhon. January 16, 2019

An abundance of insects that favor tomato plants exists in Thailand. The insect pests that devour tomato plants in northeastern Thailand include, but are not limited to leaf miners, aphids, thrips, whiteflies, and cotton bollworms. Leaf miners are insects that, in their larval state, eat through the surface of leaves until they are ready to advance to later stages in their life cycles. The effects of these larvae devouring the plants are nonlinear white trails in the plant leaf surface as seen in Figure 4. These trails in the plant leaves cause the plant to become susceptible to disease, and potential plant cell death. One of these leaf miners is *Liriomyza bryoniae*, which in its later stage of life becomes a yellow and black fly called a Liribo. Thailand's approach to dealing with these pests are insecticides (R.J. McGovern, 2016).

Figure 4. Leaf Miner Damage in tomato plants in Sakon Nakhon. January 16, 2019

2.3.2 Poverty

Many farmers in Thailand are in debt. In 2011, the National Bureau of Statistics announced that about two out of three farming households incurred debts of about $4,388 USD (Tapanapunnitikul, O., & Prasunpangsri, S. 2014). Thai farmers traditionally owned their land, but the introduction of money loans combined with land shortages have created a group of landless farmers. Due to these financial obstacles, farmers struggle to establish ownership rights to the lands they cultivate, and struggle to make a profit with rising supplies costs and varying seasonal prices. (Tapanapunnitikul, O., & Prasunpangsri, S. 2014).

According to the Office of Agricultural Economics in 2011, 29% of farmer household gained an average income below the poverty line of $592 USD per year. Poverty and low incomes are therefore major factors that encourage the use of pesticides to increase short-term yield and ensure a profit (Tapanapunnitikul, O., & Prasunpangsri, S. 2014).

2.3.3 The Buyer

Tao Ngoi farmers mostly sell to two main buyers, Doi Kham and middlemen who then sell the crops to markets in Thailand. Neither buyer offers greater prices for tomatoes that are completely organic. The physical appeal of the tomatoes concerns both buyers. Doi Kham will only purchase red tomatoes from farmers, and they pay a flat rate of 2.3 Thai baht per kilogram regardless of the season. The middlemen buy tomatoes of varying appeal from the farmers and sort them based on size and color. The middlemen ship greener tomatoes to markets further away from the farms, and send redder tomatoes to markets that are closer. The price varies depending on the size and appearance of the tomato. During the dry season, middlemen typically pay more for tomatoes if they look more appealing; larger, more symmetrical fruit and brightly colored. The maximum price middlemen will pay for appealing tomatoes is eight Thai baht per kilogram, while they pay six to seven Thai baht per kilogram for less-appealing tomatoes. (Unspecified Tao Ngoi Middleman Warehouse, Personal Interview, 2019, Jan 16). Some farmers sell to both middlemen and Doi Kham, while others sell to only to middlemen (Baam Na Ngoi Village Farmers, Group Interview, 2019, Jan 16). The reason Thai farmers continue to sell to Doi Kham despite the lower prices and higher regulation on tomato appearance, is the sense of loyalty they feel towards them. Doi Kham helped many farmers begin farming by providing supplies and support, as well

as helped many by introducing tomatoes to the Tao Ngoi District. Additionally, Doi Kham employs the farmer's children in their factory.

Thai farmers feel pressure to produce large quantities of crops in a short amount of time. Buyers require the tomatoes to be physically appealing and large, and they expect farmers to grow them quickly to increase sales. This pressure causes some farmers to turn to chemicals and the overuse of growth hormones in order to meet their buyer's standards. Chemicals are only a short-term solution and have many negative effects on the environment and health of the farmer. Since there is no financial benefit to switching to organic farming methods, and since adopting organic farming methods requires additional resources, farmers are even more inclined to resort to pesticides to increase profit (Bung Noi Village, Group Interviews, 2019, Jan 17).

2.4 Introducing Our Sponsor

The Tao Ngoi Pattanasuksa School, founded in 1979, is located in the Sakon Nakhon district. Its founder, Charuek Phinyapol, wanted to give young people the opportunity to receive an education locally. The first year it opened, the school had two teachers teaching two classes at the lower-secondary level. Today, the school teaches classes from pre-primary to secondary levels with a variety of subjects offered. The school emphasizes discipline and morality to its students (Tao Ngoi Pattanasuksa School, 2017). Kru Suchaya is a science teacher at the Tao Ngoi Pattanasuksa School. Kru Suchaya shared our goal of teaching farmers about the importance, benefits, and feasibility of adopting organic farming methods. As a teacher, her approach was to educate her students about organic farming methods. She made efforts to establish an agricultural club and initiated a project to educate students about how to make organic fertilizer from dry leaves and crop waste using the leaf-cutting machine. Kru Suchaya's goal for our team was to create a program to teach her students about alternative farming methods and increase their interest in organic options.

2.5 Alternatives

Organic farming is the practice of not using chemicals, unnatural or synthetic fertilizers, genetically modified organisms (GMOs), antibiotics, growth hormones, or agrochemicals. It instead focuses on the use of natural sources of nutrients such as compost, crop residues, manure, and natural methods of weed and pest control. Organic farming promotes crop rotation and encourages a balanced relationship between the crops and any beneficial organisms in the soil or surrounding ecosystems. All the waste and nutrients produced on an organic farm can be recycled back into the soil (Behera, K.K. 2012).

2.5.1 Good Agricultural Practice

Good Agricultural Practice, or GAP, is a farming standard initiated by the Thai government in 2005 to address the growing concerns for food safety and working conditions both in Thailand and globally. GAP promotes the health and safety of the environment and consumers as well as the working conditions and economic sustainability of farmers (Liu P. 2017). GAP assists Thailand in trading with other countries, especially in Europe, where food and safety standards are higher. Global GAP, initiated in 2008, is an internationally recognized standard founded and used widely in Europe, to assure

consumers about the safety of their food products. International recognition of GAP requires farmers to follow specific regulations and purchase a certification. Some standards include monitoring systems for the types and amounts of pesticides used, types of crops grown, and safety procedures of workers. Any crop sold needs to be traceable back to the farming unit where it came from. There are regulations about the storage of pesticides and the amount of pesticide residue on crops, and records kept on farming practices. These standards can cost a lot of money and labor and therefore many farms, especially smaller ones, are unable to afford certification (Roongnapa K. et al. 2015). GAP was established by food industries, producers, and government organizations concerned with the quality and safety of food being sold in Thailand and the standards of their buyers overseas (Liu P. 2017).

2.5.2 Effective Microorganism Technology

Effective Microorganism technology, or EM technology, is a farming approach that stimulates the natural biological activity in the soil or on a plant to increase crop yield and quality. This technique also improves the quality of the soil and the health of the local ecosystems by increasing the beneficial microorganisms in the soil. These microbes enhance the natural fertilizing process in the soil and are stimulants that increase the plants' ability to fixate nitrogen, decreasing the need for artificial fertilizers. Microbes strengthen the immune system of crops by aiding in decomposition, which provides plants with organic acids such as lactic acid, amino acids, and acetic acid, and important vitamins and minerals. EM technology involves organic matter made from recycled crops and manures that act as a fertilizer for the crops (Using EM for Agriculture. 2019). Organic fertilizers are derived from animal matter, animal and human excreta, and vegetable matter. Naturally occurring organic fertilizers include animal wastes from meat processing, peat, manure, slurry, and guano.

Soil inoculants are microbes in the soil that release important enzymes. Soil maintenance is very important when growing tomatoes because there are thousands of microorganisms living within the soil. These organisms affect the chemical and physical properties of the soil, which have a role in the health of the plants. Ways to maintain soil organic matter include adding manures and composts, incorporating crop rotations, and growing cover crops. Recycling organic material in the soil increases microorganism diversity and soil health. Soil inoculants have beneficial effects on the soil or plant and protect the plant from harmful organisms. The main kinds of inoculants are biofertilizers, biopesticides, and plant resistance stimulants. The use of soil inoculants as a farming technique started in the 1890s and its results depend on the type of plant, the plant species, and the soil characteristics; the pH, moisture content, organisms present, and temperature (Gaskin J., et al. 2013).

2.5.3 Fermented Juices

Fermented juices are made of ripe fruits, vegetables, and root crops and are applied to plants to enhance their quality. Fermented juices also act as a fertilizer by replenishing soil nutrients depending on the ingredients used. They are a type of Effective Microorganism technology as they are made of ingredients that contain microorganisms. According to The Golden Jubilee Museum of Agriculture, one can obtain important plant hormones from various recipes, which use readily available ingredients. Coupling these recipes with fermented juices increases their effectiveness. One recipe, for example, utilizes eggs and aids in increasing crop growth rates. Fruits such as bananas, pineapples, cantaloupe, and molasses improve the size of flowers and fruits. The museum staff also demonstrated recipes that can

make insecticides from herbs. One such recipe involves rice whiskey, vinegar, molasses, microorganisms and various herbs to prevent pests from damaging plants (The Golden Jubilee Museum of Agriculture Staff. Group Interview 2019, Jan 25). See Appendix F - Questions for The Golden Jubilee Museum of Agriculture Staff.

2.5.4 Mulch

Recently, the Tao Ngoi Pattanasuksa School director purchased a leaf-cutting machine that breaks down leaves for use in mulch and fertilizer. Organic mulch provides many benefits to target crops and reduces the need for herbicides. Weeds compete with crops for light, water, and nutrients, greatly affecting the quality and quantity of the produce. Malnourished plants cannot grow as big and are not as resistant to diseases as those that are able to grow free of weeds. Worldwide, 34% of crop loss is due to weeds, which explains why herbicides are the most purchased pesticide globally. Mulch stops weeds from growing, regulates soil temperature, and traps moisture in the soil, allowing target crops to thrive (Tao Ngoi Pattanasuksa School faculty, Group Interview, 2019, Jan 17).

2.6 Educational Techniques from Past IQPs

Some WPI interactive qualifying projects (IQPs)in the past have educated students through programs or a curriculum. From these IQPs we read about successful and unsuccessful techniques to teach students and factors that affect the program's educational effectiveness. This section focuses on the different approaches taken to convey information to adolescents in varying parts of the world.

2.6.1 Past IQPs

A past IQP titled *A Sustainable Science Laboratory Program for Rural Thailand* (March 2008) sought to develop an engaging, educationally valuable, sustainable laboratory program for lower-secondary school students in Sakon Nakhon. The IQP's report provides insightful recommendations and potential challenges on how to effectively engage Sakon Nakhon students in Secondary Schools in educational activities. (Briskey, E. J., Et Al, 2008)

This IQP reported that Thai teachers in these schools are particularly passionate about subjects related to pollution, including pesticide contamination. Students were more receptive to hands-on activities, and visual aids stood out as an effective means of education because they bypass any sort of language barrier existing between the team and the students. The IQP presents potential challenges in executing a successful science-based education program to secondary students in the Tao Ngoi district reported by the reviewed IQP. Students were hesitant to request help. This finding aligns with a common belief in Thai culture, which is to avoid requesting clarification on topics in an effort to avoid offending the speaker. In addition, students were less motivated to participate if in larger groups of 40 compared to smaller groups of 30 students. (Briskey, E. J., Et Al, 2008).

Another past IQP titled *Promoting Active Teaching Methods in Rural Thailand: A Case Study on Science Laboratory Active* (March 2009) focused on helping teachers in Sakon Nakhon increase science literacy by designing and implementing science experiments for the students in the Kusuman District. Grades 7, 8, and 9 of the Potisan Wittaya School and the Baan Na Peang Sawaang Wittayanukul School

were participants in the activities developed. The project's outcomes report on how well students respond to varied activities (Miranda, K.L. et al. March 2009).

Miranda et al. found that students were most receptive to engaging laboratory activities that dramatized the scientific concepts. Each program included approximately 15 minute activities performed during a full 50-minute class period. One activity included an experiment where fertilizer can grow algae via chemical reactions. Miranda et al. successfully tested the experiment in Bangkok, however, the experiment failed once performed in Sakon Nakhon. Miranda et al. believed that differences in fertilizer between Bangkok and Sakon Nakhon caused the experiment's failed reproducibility.. Despite the experiment's failure, this team observed the students expressing excitement when using lab equipment, such as microscopes and weighing scales. This team incorporated pre-program surveys and post-program surveys as indicators of program short-term effectiveness. Overall, this IQP's team found that short 15-minute activities were adequate amounts of time to effectively teach students (Miranda, K.L. et al. March 2009).

3. Methodology

The goal of our project was to develop a program for students to provide information on alternative farming methods to reduce pesticide use and encourage the switch to more sustainable farming methods. We achieved this goal by accomplishing these objectives:

1. Obtain information to identify the problem and potential solutions through interviews, focus groups, and onsite observations.
2. Choose learning objectives for the program using the information obtained from interviews, focus groups, and site visits.
3. Pilot a program using effective educational techniques to teach students about organic farming and gather feedback about its success.

3.1 Objective #1: Obtain information to identify the problem and potential solutions

We obtained information about farming practices through interviews, focus groups, and site visit observations. We chose interviews and focus groups as our method of data collection because we wanted to have open discussions. We were able to find very little background information on the farmers of Sakon Nakhon and wanted to fully understand their perspective of the problem. Semi-structured interviews and focus groups allowed us to keep the questions on the topic of our project without restricting the information we collected.

3.1.1 Means of record keeping

We conducted and recorded all interviews in Thai and then translated to English for our report. It is possible that some information or context was lost in translation. We prevented this issue as much as possible with thorough discussion and review of the notes with our Thai group members.

3.1.2 Interviews

We interviewed staff members of Tao Ngoi's Ministry of Agriculture and local farmers. Based on the farmers' availability we spoke to them through semi-structured door-to-door interviews and three focus groups of seven to nine local farmers. See Appendix D - Questions for Ministry of Agriculture of Tao Ngoi District and Appendix C - Questions for Farmers. These interviews increased our understanding of the influence of pesticides among the farms of Sakon Nakhon. They also helped us determine farmers' understanding of organic farming methods and the benefits of growing organic crops. We wanted to learn what factors influence the farming practices a farmer chooses and how likely a farmer would be to consider adopting another practice. We also asked farmers what they believed were the biggest challenges they currently face. These focus groups helped us to identify what areas farmers are inexperienced in, and to determine what information the community would be receptive to. This information helped us design our program to include material that was more applicable and helpful to the farmers.

We interviewed Kru Suchaya, a science teacher at the Tao Ngoi Pattanasuksa School, and conducted semi-structured focus groups with students. See Appendix A - Questions for Kru Suchaya, and

see Appendix B - Questions for Student Focus Groups. The goal was to understand how successful Kru Suchaya's initiatives have been, what teaching methods she believes work best, and what activities she thinks the students would enjoy most. Our team asked for student opinions on past agricultural programs held at the school, why they were not successful, and what would increase interest in an agricultural program in the future. We also learned what students like to do in their free time, and determined how much they know about pesticide use and organic farming to identify gaps in information.

We organized an informal interview with Professor Wangsomboode at Chulalongkorn University, who specializes in microbial diseases, and Professor Buntika Areekul Butcher, who is familiar with various insects in Thailand. See Appendix G - Questions for Chula Botanical Professor. The goal was to identify the microbes damaging Sakon Nakhon's tomato plants. We used the pictures of the plant damages taken during the first site visit to identify the pests.

3.1.3 Site Observations

We observed current farming practices on organic and non-organic farms. We also looked at some of the crops the farmers grow on these farms. We asked farmers to show examples of healthy and damaged tomato plants to help us visualize the impairments and help us identify possible causes. The information we obtained from site observations helped determine alternative farming methods that were feasible for the farmers. Our team took pictures for our program and final report.

3.2 Objective #2: Choose learning objectives for the program

We chose the learning objectives for the foundation of our program using the information obtained from interviews, focus groups, and site visits. The learning objectives aimed to fill the gaps in information discovered after completing Objective 1. Our goal was to ensure that students finished our program with new knowledge in each learning objective.

We analyzed data obtained from interviews, focus groups, and site visits using a coding method. We grouped all of our data based on whom we obtained the information from, who the information effects, and common trends of information such as farming techniques, pesticide usage, and educational methods. We then quantified the interviews, focus groups, and site visit information using these categories to visualize which factors have the most influence. We evaluated and categorized our data to organize the significant information obtained. The important information allowed us to understand the problems farmers are facing so we could determine the best methods to help improve their quality of life. It also allowed us to understand how to improve the agricultural club at school to interest students.

3.3 Objective #3: Pilot a program to teach students about organic farming

Our team piloted a program using effective educational techniques to teach students about organic farming and gather feedback about its success. We consulted experienced educators to identify these techniques and get recommendations on how to implement them. We used the educational techniques to develop our learning objectives into engaging activities.

We spoke to experts at the Science Center for Education to collect data on the best methods to run a program for Thai students. This was necessary because the Science Center for Education conducts programs often and therefore understands the best methods to interest students. We used the results of the interviews to generate engaging activity ideas for the pilot program.

Our team interviewed Kru Suchaya, the faculty advisor of the agricultural club at the Tao Ngoi Pattanasuksa School, to understand how the club runs. We asked her about the success of the club's programs and how she makes her lessons interesting for her students. We used the information about the club's successful and unsuccessful activities to increase our program's chance of success. Before piloting our program, we sent our plan to Kru Suchaya for final advice and so we could coordinate supplies.

We piloted the program at the Tao Ngoi Pattanasuksa School with a class of 8th-grade students. First, we had the students take a brief test that covered the material of our program to obtain a baseline of their previous knowledge. See Appendix H - Program Quiz Questions. We later used the results of this test as a baseline for comparison. We then set up multiple stations with activities that presented material on the target topics and then tested them on what they learned. We took notes on the effectiveness of each station based on student participation and engagement. To quantify the results of our program we had the students take the same test we gave them before the activities. Our team compared the results of the second test to the results of the first test to quantify the information the students retained. In addition to knowledge quizzes, we also administered a feedback survey to receive student feedback on our program. See Appendix I - Program Feedback Survey Questions. It was important for us to pilot the program ourselves so that we provide tested and informed recommendations to the school. We then revised the program based on the feedback and observations to improve its effectiveness. Our team assessed the strengths and weaknesses of each activity and made appropriate changes. These changes provided solutions to issues we encountered when piloting the program.

4. Results and Analysis

Interviews and site visits helped us understand the underlying problems behind pesticide use in Tao Ngoi and how to effectively run an educational program for 8th-grade students. In this chapter, we discuss common farming issues that influence pesticide use among farmers and the organic solutions around which we developed our program. We then detail the methods we learned to engage and educate students, our program effectiveness, and discuss any limitations we faced during the pilot.

4.1 Farming Methods

Interviewing farmers allowed our team to determine important information about current farming techniques. The information we collected is outlined in four main findings: (1) The health hazards of pesticides concern farmers, but farmers use pesticides to combat tomato pests and diseases; (2) Costs are a major factor in determining farming techniques; (3) Farming techniques vary depending on village; (4) There is a successful case of 100% Organic Farming in Sakon Nakhon. While on-site, our team attempted to gather information from both organic and non-organic farmers. However, many of the farmers who primarily used pesticides chose not to interview with us, which limited the information on the extent of pesticide use.

4.1.1 The health hazards of pesticides concern farmers, but farmers use pesticides to combat tomato pests and diseases

From our focus groups and interviews with farmers, we learned that many farmers are conscious of the negative health effects of pesticides. Common problems with pesticide use on farms included contamination of water sources, infection of open wounds, and dangerous chemical blood levels in farmers. In some cases, farmers who once relied on chemicals switched to organic methods after experiencing skin irritations. Some farmers practiced some organic farming to reduce their pesticide use in light of these health risks, but contaminated water sources still exposed their crops to high levels of chemicals.

Farmers take measures to protect themselves while spraying pesticides and preserve their health. However, high levels of chemical residue are more common among harvesters who do not wear as much protection as pesticide sprayers. The ministry of agriculture informed us of one farmer who had chemical residue in her bloodstream and confirmed her job was to harvest the fruit from the fields, not apply the chemicals to the crops.

Our interviews confirmed that farmers use chemicals on tomatoes because they are vulnerable to many diseases and pests. We learned that many tomato farmers see green and yellow leaf disease among their crop, a very prevalent disease in Tao Ngoi that can spread quickly to surrounding plants. Many farmers also mentioned worms and bacteria in the soil that can damage the tomato plant, making the product unappealing to buyers. We learned that most farmers use chemicals as the last resort to combat these issues if an organic alternative is unknown, ineffective or not feasible. Overall, farmers did not have the resources to investigate organic alternatives on their own and relied heavily on farming knowledge that passed down from family members and neighbors. See Table 1 for a list of chemicals used to combat these issues in Tao Ngoi.

Table 1. Chemicals used by farmers in Tao Ngoi to combat various crop issues

Crop Issue	**Chemicals**
worms	Chlorantraniliprole, emamectin benzoates
Fungi *e.g. Downy Mildew*	Bochum, thiazole carboxamides
Blossom-end Rot, green leaf wilt	Calcium boron
Rice Thrips	cabaryl
Aphids, plant louse	neonicotinoid
weeds	Glyphosate, paraquot

4.1.2 Costs are a Major Factor in Determining Farming Techniques

Many farmers expressed that the cost of tomato farming was very high and sometimes unsustainable. Many farmers did not grow tomatoes because they were spending too much money on tomato care, and not making enough selling the crop. One farmer said they invested about 15,000 Thai baht into their tomato crops, but only sold them to Doi Kham for about 12,000 Thai baht.

From our interview with the assistant director of the Ministry of Agriculture and cooperatives under the Department of Agricultural Extension in Tao Ngoi District, we learned about farming techniques currently used by farmers in this area. We discovered that farmers use a mixture of organic matter, such as cow or buffalo manure, and chemical fertilizers to increase yield- and reduce cost. Organic fertilizer on its own is beneficial for the soil but is slow acting. Plants absorb chemical fertilizer quickly, which helps farmers meet their quota on time. Farmers add manure to increase the amount of fertilizer at a low cost. Some farmers use compost they make from recycled plant waste and fermented juices on their fields as sources of nutrients. They mentioned a fungus, Trichoderma, which is present or added to the soil and acts as a naturally occurring biocontrol agent as it produces many enzymes that benefit crop production. Farmers can breed their own Trichoderma or purchase them from the fertilizer and pesticide stores.

We interviewed the assistant director of the Tao Ngoi Pattanasuksa School and learned about the surrounding villages and companies associated with pesticides. He told us many private companies give farmers synthetic fertilizers for free to test their products. According to a teacher at the Tao Ngoi Pattanasuksa School, chemical fertilizer sellers are not concerned about the effects of their products and are only interested in making a profit. Farmers are therefore more likely to use synthetic fertilizers if they receive them free rather than purchasing a more organic product that costs more.

4.1.3 Farming Techniques Vary Depending on Village

Our interviews with farmers revealed that farming techniques and knowledge on organic farming methods varied depending on the village. Three of the four villages we spoke to were aware of organic

fertilizer, GAP, crop rotation and using fermented juices as alternatives to pesticides while the remaining village relied solely on chemicals. Farmers from Baan Na Ngoi Village were all aware of GAP and they explained that Doi Kham and the middlemen have expectations for the quality of the tomatoes; they will not buy tomatoes for the same price if they do not look visually appealing or are not big enough. The middleman will typically buy the tomatoes when they are yellow or red, but Doi Kham will only buy red tomatoes. Doi Kham requires certain GAP standards of the products they purchase and will buy tomatoes for 2.3 Thai baht per kilogram if farmers meet these standards. However, the farmers expressed difficulty in meeting their tomato appearance standards while farming completely organically. They use insecticides to defend against tomato diseases but do not use chemicals on any of their other crops.

Different villages have different farming techniques depending on the crops they grow, the type of soil they use, the amount and quality of water they have access to, and how they were taught to farm from older farmers and family members. Farmers' relationship with Doi Kham also seemed to play a role in farming choices. The farmers from the Baan Phon Plaa Lor Village sold primarily to Doi Kham who has standards for all products they purchase. When asked why they sell primarily to Doi Kham even though the middleman offered a higher price, they said that they want to support Doi Kham and its initiatives. Doi Kham has a history of aiding the community with many job opportunities. This encourages the farmers to sell mostly to Doi Kham and practice more sustainable farming methods to meet their requirements (Baan Phon Plaa Lor. Group Interview, 2019, Jan 16).

4.1.4 There is a Successful Case of 100% Organic Farming in Sakon Nakhon

During our door-to-door interviews with farmers, we met a farmer who claims to grow completely organic tomatoes. His success was due in part to his readily accessible supply of natural fertilizer, made from cow manure. His techniques for combating the severity of tomato diseases included mixing sand with the soil, resting the soil to promote nutrient regeneration, and spraying fermented juices on the plant leaves and fruit to combat pests. Figure 5 shows some of his fermented juice recipes contained within plastic liter coke bottles. He learned many of these recipes and techniques from Organic Farming workshops and is currently experimenting with different formulas to constantly improve his crop production.

4.1.5 Organic Farming may offer a Financial Advantage

As shown in Figure 6, the organic farmer's tomatoes were noticeably red and large (See Figure below). On average, he sells his tomatoes to the middleman for eight Thai baht per kilogram as opposed to the standard four Thai baht per kilogram due to the high quality and appeal of his tomatoes. Additionally, his organic techniques do not negatively affect his tomato production, so he is still able to sell his tomatoes to the factory and middlemen as usual. This suggests a financial advantage to organic farming of which not many farmers in the area are aware.

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Figure 5. Fermented juices brewed in one-liter bottles in Sakon Nakhon. January 16, 2019

Figure 6. Large, healthy tomatoes grown organically in Sakon Nakhon. January 16, 2019

4.2 Program Development

Interviews with representatives from The Science Center for Education and Tao Ngoi Pattanasuksa students informed our team on how to create a successful program.

4.2.1 Effectively Engaging Students

We decided that students would be the best audience for our program as they would relay the information to their parents, who were mostly farmers (Tao Ngoi Pattanasuksa School Students, Group Interview, 2019, Jan 17). Specifically, we invited 8th graders as our program participants since we wanted to observe how receptive they would be to our learning objectives and activities. Grades 7 and 8 expressed the most interest in learning about organic farming and the agricultural club comprised mostly of 7th and 8th graders. We believed this age group would be most responsive to the information in our program and be able to maintain focus while interacting with the material.

Representatives from the Science Center for Education staff advised us on how to effectively interest and educate children. We learned that hands-on, interactive activities are the best means to interest and educate 8th-grade students. Involving games and student performed experiments or activities would stimulate student interest and learning capacity. Incorporating technology and smartphones would also appeal to the students, many of which own smartphones and use them every day. The representatives also suggested we separate the learning objectives into several stations and only use key points to convey our message as large amounts of information can be difficult for students to absorb. Each station should be around 25 minutes long to keep students attentive and be monitored by at least two staff members to better manage the students (Science Center for Education Staff. 2019, Jan 23). Group Interview. See Appendix E - Questions for Science Center for Education Staff.

After interviewing the students at the Tao Ngoi Pattanasuksa School we learned about their interests and extracurricular activities which we could incorporate in our program. Many students had career interests other than farming such as medicine, accounting, engineering, sports, the military, and

teaching and expressed interest in living in a city, such as Bangkok. Most students expressed interest in an agricultural club but found it was difficult to find time to attend meetings. The club usually meets during students' free period when they would rather play sports or finish homework, but incentives such as extra class credit were a common motivation for attendance. See Appendix B - Questions for Students.

4.2.2 Learning Objectives

Our program aimed to offer organic solutions to common problems experienced by farmers in Tao Ngoi. From our Tao Ngoi observations, interviews, and focus groups, we identified three problems to address in our program. First, farmers suffer from poverty and could benefit from an increase in profit from crop sales and a decrease in farming costs. Second, tomatoes are susceptible to various diseases and pests and farmers do not know organic methods to mitigate them. Third, some farmers use dangerous herbicides, putting the community at risk of health issues.

We sought to combat these problems by developing our program around three learning objectives. Each learning objective correlates to mitigating one or more of the problems we chose to target in our program. First, we planned to teach students about the benefits of using mulch. Mulch can serve as an alternative to herbicides, regulate soil temperature, and trap moisture in the soil. Additionally, farmers in Tao Ngoi can obtain mulch with minimal financial obstacles with the availability of the community mulch machine. Second, we planned to teach students about the benefits and feasibility of crop rotation. Crop rotations can mitigate the spread of disease through the soil and replenish nutrients in the soil. Third, we sought to teach students about the effective microorganism technology, or EM technology. Utilizing EM Technology in one's farm can reduce disease among tomato plants, and produce larger, higher quality tomatoes. Producing more successful tomato crop yields would increase selling prices, thereby increasing farmer profits.

4.3 Program Evaluation

We used the knowledge quizzes and feedback surveys to evaluate the short-term success of our program and took notes about student excitement, participation, and any problems that occurred.

4.3.1 Limitations

Students experienced difficulty accessing the internet. The Tao Ngoi Pattanasuksa School provides students with access to Wi-Fi. However, students explained that the Wi-Fi was not strong enough to load web pages or download apps. To provide students with sufficient access to Wi-Fi, our team resorted to using the hotspot application for smartphones.

Not all students possessed smartphones ready for the activity. To solve this issue, we grouped students into teams for activities involving smartphones and internet access. They chose to group themselves up into teams consisting of 2-3 people. This not only made up for the lack of devices but also encouraged teamwork and collaboration.

The light-microscopes malfunctioned frequently. The light in the microscopes would dim after a few minutes and had to be turned off and back on again. We had to keep the microscopes that were not

in use off and only turn them on when students were looking at organisms to preserve the light bulb. We recommend testing the microscopes before use in activities to ensure they do not hinder the activity.

Having students make their own microscope slides was not efficient or effective. The slides made by students did not show any organisms when looked at under the microscopes. It also took a lot of time for students to make their own slides and focus on the microorganisms as many did not know how to use a microscope. We chose to make the slides ourselves and have the students look at them. This way we could make sure the right amount of EM technology was on each slide to effectively visualize the microorganisms. If students were to make their own slides, they would need to learn how to properly make a slide and operate a microscope prior to the activity.

4.3.2 Effectiveness of Program

Based on observations taken during the program, we were able to see the students' reactions to our activities. As suggested by the results of the post survey, students enjoyed interactive activities such as the fermented juice recipe game where they were racing to gather the ingredients to complete the recipe. See the post survey results in Appendix K - Post-Program Quiz and Survey Results. Students also enjoyed the Kahoot quiz game where they used their smartphones and competed against their friends. Finally, we found giving students prizes for answering questions or winning an activity increased interest and enthusiasm for that activity.

The quiz given before and after the program gave our team insight into the effectiveness of our activities and teaching methods. The average score on the quiz given before was 43.54% while the average score on the quiz given after the program was 90%. The quiz results reside in Appendix J and K. The survey given after the program was for us to learn what the students liked and did not like about our activities so we could revise the program before making final recommendations to the school. 30 out of the 40 students who took the survey said their favorite activity was the Kahoot game. See Appendix K - Post-Program Quiz and Survey Results. When our team analyzed answers from the Kahoot game, the average score was 82.12%. See Appendix L for the complete Kahoot game results. These scores demonstrate that our program was successful at relaying information the students could understand and remember and that our activities effectively engaged student interest.

Kru Tom told us she is setting up a workshop to take place next month, March 2019. The workshop includes similar topics to our program. She invited the farmer our team spoke to who has a completely organic farm to come speak at this workshop. He will talk about his experiences as an organic farmer and the benefits of having an organic farm.

5. Recommendations and Conclusions

Our team developed recommendations based on background research and feedback from the piloted program at the Tao Ngoi Pattanasuksa School. This section will discuss recommendations to revise and sustain the program, increase awareness of pesticide use and ways to promote alternative farming methods among farmers.

We recommend the Tao Ngoi Pattanasuksa School run the farming program every year with the help of the agricultural club. We revised the program based on feedback and included detailed instructions on how to run each activity. Our team recommends putting on this program every year with the help of the agricultural club and following the directions in Appendix M. Students would attend during their free period and would receive extra credit towards their final science grade as an incentive for participation. During the free period, students in the agricultural club can come up with some activities based on our recommendations from program revisions in Appendix N. The program can be tailored to suit time constraints or to occur more frequently. We recommend promoting the program on Facebook and giving out prizes that Kru Suchaya can fund using an already existing budget awarded to her for her work with organic alternatives.

We recommend Kru Suchaya rename the agricultural club to be more appealing to students, such as the science club. We believe the name should convey a fun yet educational purpose to attract student interest.

We recommend developing a database with information on pesticide use in Sakon Nakhon. During our initial research, we struggled to find information and data on pesticide use in Tao Ngoi. Such information was also not available from constituents at the Tao Ngoi Ministry of Agriculture. Therefore, we recommend the Ministry of Agriculture establish an up-to-date database, with information and statistics on the types and quantity of pesticides farmers use. We also recommend the Ministry of Agriculture collaborate with Doi Kham to develop and maintain this database as they are influential in the district of Tao Ngoi and are directly connected with the farmers.

We recommend the Tao Ngoi district create a schedule for workshops farmers can attend to learn about organic ingredients and methods. Another recommendation our team has for the district of Tao Ngoi is to promote attendance of farming workshops. When our team interviewed farmers, a few explained they learned about organic farming methods from workshops. The Ministry of Agriculture in Sakon Nakhon offers organic farming workshops that are free and open to all farmers to help mitigate pesticide issues but attendance is low due to poor promotion and scheduling. We recommend encouraging farmers to attend workshops by creating a schedule including the time, location, and topics of the workshops available and sharing this information through flyers, word of mouth and on the radio.

We recommend Doi Kham provide financial incentives for farmers to switch to organic farming methods. During our site visit, we learned that Doi Kham requires certain GAP standards but do not pay more for organic crops. Therefore, we recommend Doi Kham encourage farmers to adopt alternatives to pesticides by offering incentives for using organic methods.

The goal of our project was to create a program for students at the Tao Ngoi Pattanasuksa School on organic alternative farming methods. The objective of this program was to address the issue of

pesticide overuse on farms in Sakon Nakhon. We interviewed farmers from the Tao Ngoi district and the Ministry of Agriculture as well as students from the Tao Ngoi Pattanasuksa School and the Science Center for Education to gain information about pesticides and teaching techniques for our program. We piloted the program successfully, made revisions, and provided our sponsor with instructions to run the revised program. We made recommendations for the Tao Ngoi Pattanasuksa School and the Tao Ngoi district from information we obtained in interviews and from piloting our program. These recommendations will benefit the students at the school and farmers in the district.

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Appendices

Appendix A - Questions for Kru Suchaya

1. What was included in the previous workshops?
    a. Coconut dust, peat moss (SRI?), tomato waste, compost piles, EM Technology?
2. Why do you think the students were not interested in the previous workshop?
    a. Have similar courses been offered in other schools?
        i. Have those courses been successful?
3. How were the previous workshops marketed?
    a. How successful were extra credit incentives?
4. What do you think would be effective education techniques to attract student interest?
5. What was the structure of the previous workshop?
    a. Was it interactive or hands-on?
6. How did the agricultural club operate when it was active?

Appendix B: Questions for Student Focus Groups

1. What do you like to do in your free time?
2. What don't you like?
3. What do you want to be when you grow up?
4. What are you favorite classes?
5. What do you know about Organic Farming?
    a. Be ready to explain [Coconut dust, peat moss (SRI?), tomato waste, compost piles, EM Technology], and the benefits [health, money over time] the best we can for kids
6. Are your parents farmers?
7. Would you join the agricultural club/attend our program? If extra credit is given?

Appendix C: Questions for Farmer Focus Groups

1. What crops do you grow?
2. What destroys your crops? (Weather, Insects, Rodents, other?)
3. Are you familiar with the Mulch Machine that is available?Have you been trained on how to use it?
4. What pest issues do you have on your farm??
5. What form of pest management do you use?
    a. (If Pesticides) How much do you need to use to kill them?
    b. (If pesticides) Do you know any impacts pesticides have on your health or the environment?
    c. (If organic) What are your motivations for using organic pest management methods?
    d. (If Organic) How did you learn these methods?
6. Have you ever heard of the term “Organic”? What does that mean to you?
    a. (Be ready to provide all of the information we have on organic farming thus far)
        i. Coconut dust, peat moss, tomato waste, compost piles.
7. Have there been major health issues / illnesses that happen often in your community?
8. What do your kids want to be when they grow up?
9. How were you taught to farm?
10. Have you been given any training recently in the past few years?
11. What is your relationship with Doi Kham like?

Appendix D: Questions for Ministry of Agriculture of Tao Ngoi District

1. What do you think are the greatest obstacles preventing farmers from switching to organic farming?
    a. (Definition of organic farming: Not using pesticides or synthetic fertilizers. Instead, using alternative means of pest management such as crop rotations and/or EM Technology. Also, using mulch, coconut dust, peat moss (SRI), tomato waste and/or compost piles to replace synthetic fertilizer)
2. What ends up destroying crops here in Sakon Nakhon? (Weather, Insects, Rodents, other?)
    a. Goal with this question is to identify the insect pest culprits to better decide on the best organic farming methods to employ
3. Do you think farmers are abiding by the GAP, Good Agricultural Practice, standards in Tao Ngoi?
    a. What percentage of farmers?
    b. How many farmers in Tao Ngoi?
4. Do you have any data regarding the use of pesticides among farmers of Sakon Nakhon?
5. Do you have any data regarding the use of organic farming methods among farmers of Sakon Nakhon?
6. Do you have any data indicating how many young people are going into farming?

Appendix E: Questions for Science Center for Education Staff

1. What type of activities are good for middle school students?
2. What activities have you done or have set up in the past that were successful? (that students enjoy)
3. Have you done activities about agriculture before?
4. Do you know any farming activities?
5. Do you have any advice about setting up activities for students?
6. What should we be most concerned about when designing activities?
7. If we have a lot of information, how should we organize it?

Appendix F: Questions for The Golden Jubilee Museum of Agriculture Staff

1. What activities have you done with the kids before?
2. What types of activities are suitable for the middle schoolers?
3. Do you use organic fertilizer on your farm?
4. Do you have any recipes for organic fertilizer and fermented juice?
5. How does the royal project help in reducing chemical usage in agriculture?
6. What type of activities do students enjoy the most?
7. Do you use EM technology here?
8. Do you have any other alternatives for EM?
9. What are the principles of crop rotation?
10. Is there any solution to green and yellow wilt disease for tomatoes?
11. Do you use mulch?
12. How does mulch help?

Appendix G: Questions for Chula Botanical Professor

1. What are the most prevalent diseases and microbes that harm tomatoes?
2. Is there any way to prevent these things from happening besides using chemicals?
3. How can you tell what disease a tomato plant has?
4. How do you make organic fertilizer?

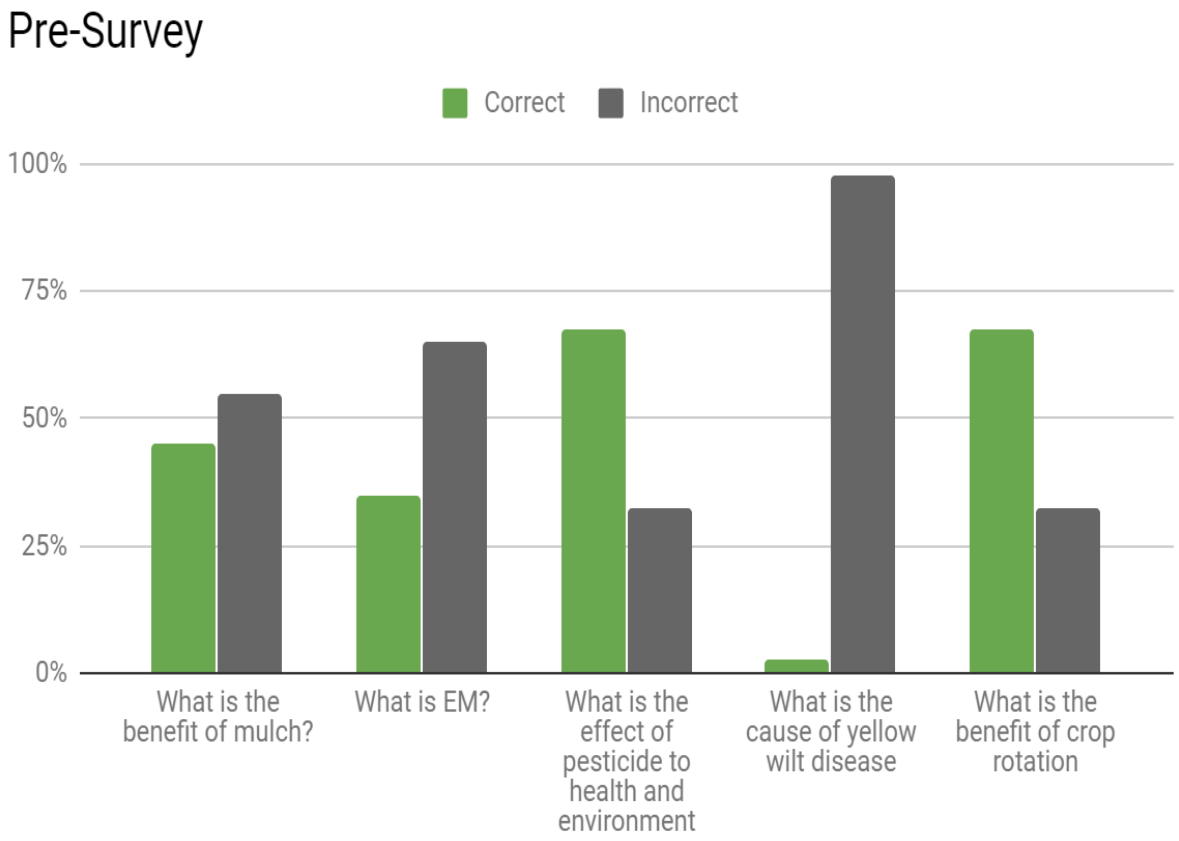
Appendix H: Program Quiz Questions

1. What is the benefit of mulch?
2. What is EM?
3. What is the effect of pesticide to health and environment?
4. What is the cause of yellow wilt disease?
5. What is the benefit of crop rotation?

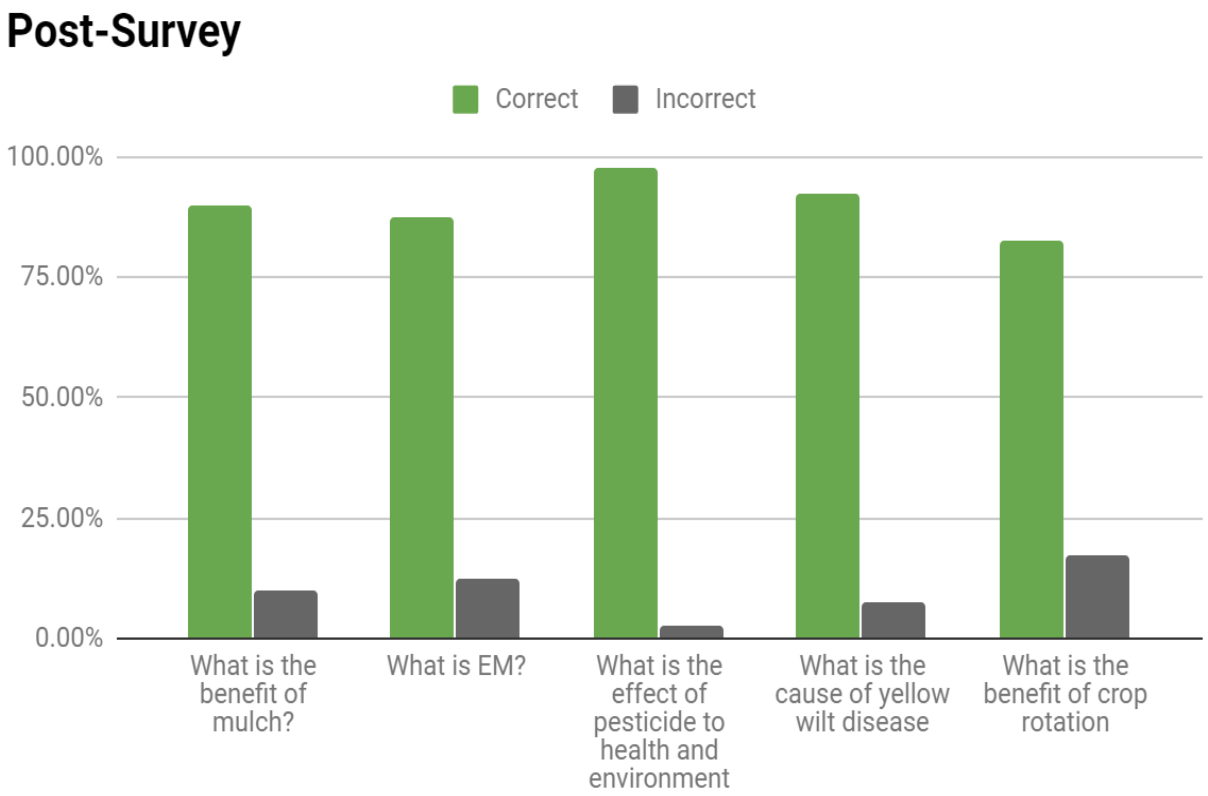
Appendix I: Program Feedback Survey Questions

1. What was your favorite activity?
2. What part of the program that should be improved?
3. If we set up a program like this again, do you want to join again?
4. What did you learned from this program?

Appendix J: Pre-Program Quiz Results



Appendix K: Post-Program Quiz and Survey Results



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1. What is your favorite activity?

a.

Activity	Number of ppl	Percentage
Kahoot	30	75.0
Microscope	4	10.0
EM	4	10.0
Every activities	2	5.0

2. What part of the program that should be improved?
    a. All of them said none, and one of them said that we should give out more prize
3. If we set up a program like this again, do you want to join again?
    a. All of them said yes
4. What did you learn from this program?

a. 47.5% said that they learned more about microorganisms (shape of bacteria, the benefits of EM, and how microorganisms work)
b. 20% said that they learn more about EM and fermented juice recipe
c. 32.5% said they learn more about organic farming

Appendix L: Kahoot Quiz Game Results

Final Scores				
Rank	Players	Total Score (points)	Correct Answers	Incorrect Answers
1	K.T.	11141	9	1
2	Po&Tukta	10668	9	1
3	Bad boys	9531	9	1
4	จรวดขึ้นฟ้า	8107	8	2
5	Slots	7882	8	2
6	Benz	6918	7	2
7	ม่อนเอง & วอม	6888	7	3
8	TP	4560	5	5

เกมเพื่อผ่านไปด่านต่อไป	
Played on	12 Feb 2019
Hosted by	bsacissp
Played with	8 players
Played	10 of 10 questions

Overall Performance	
Total correct answers (%)	78.48%
Total incorrect answers (%)	21.52%
Average score (%)	82.12%

Appendix M: Revised Program Details

Station	Time	Instructions	Preparation	Materials needed
1 Intro	5 mins	**1.** Introduce program host(s) **2.** Give a brief explanation of the program **3.** Divide students into two teams of 20 or less	N/A	N/A
2 QR Code Hunt	15 mins	*This game can be done in teams (no more than four teammates) or individuals* **1.** Each team has to find all five QR codes **2.** Kahoot Game is based off information on five QR codes	**1.** Print multiple copies of QR codes and tie it around an open area **2.** Program hosts check that each team has captured all five QR codes	**1.** Content to put in each QR code **2.** Printed QR code **3**. Plastic bag **4**. Rope **5.** Good internet connection
3 Kahoot Quiz	30 mins	**1.** Give students five minutes to read and memorize QR codes **2.** Show them how to register on Kahoot **3.** Start the quiz **4.** At the end of each question explain the correct answer **5.** Hand-out prizes to top teams (Two teams with the highest score win the big prize. Third, fourth, and fifth place win a small prize).	**1.** Questions for Kahoot are related to the content in the QR code **2.** Prepare an explanation for each answer	**1.** Good internet connection **2.** Big prizes **3.** Small prizes
4 EM Tech	15 mins	**1.** Give general information about - What EM technology is - How EM works - Benefits of EM **2.** Look at examples of microorganisms under a microscope **3.** Students make their own sample slide from the fermented juice	**1.** Prepare the sample slides **2.** Prepare the empty slide and cover slid to be ready to use (to test with fermented juice)	**1.** Microscope **2.** Smart lens **3.** Slides
5 Fruit Cut-out Game	15 mins	**1.** Divide the students into teams of five or less **2.** Teams will be given a fermented juice recipe to complete **3.** Teams must gather fruit cutouts according to the recipe from an ingredient table and bring them to an empty table for the program hosts to check **4.** The first team to get all ingredients earns a point **5.** The team that earns two points out of three games wins the prize	**1.** Arrange the fruits cut out in any order you want **2.** put them in the distance so that students will be able to run to get the ingredients	**1.** Cutouts of ingredients **2.** three different fermented juice recipes **3.** prizes