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Hydroponics at Wat Pathumwanaram School: Hands-on Learning through Soilless Gardening

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Hydroponics at Wat Pathumwanaram School:
Hands-On Learning through Soilless Gardening

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by

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ABSTRACT

As a modernizing nation, Thailand is boosting its economy by increasing the level of education of its workforce. The Thai Ministry of Education and royal family are reforming the system with new pedagogical methods. Wat Pathumwanaram School, in the heart of Bangkok, is looking for ways to implement hands-on education using its hydroponic garden. The project team began this implementation with hands-on activities for hydroponics booths at a school educational fair. The team also developed a school hydroponics club and tested improvements to the garden.

ACKNOWLEDGEMENTS

Our team would like to thank all of the people who have helped us throughout our project.

First we would like to thank our project sponsor, Wat Pathumwanaram School, for giving us a place to work every day, their hospitality, and their input during our project.

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EXECUTIVE SUMMARY

Thailand's primary and secondary education system may be its single greatest asset in its development from third-world poverty. However, data show that the Thai rate of attendance in upper secondary school must climb above the 2008 figure of 59.4% if the country is to continue to develop and be able to compete in an increasingly knowledge-based global economy (UNESCO Bangkok, 2008) (Apostol, 2004). Studies and first-world examples further suggest that moving away from rote learning and modernizing teaching methods will increase the economic utility of education that does take place. Educational development programs run by the Ministry of Education, Thai royal family, and Bangkok Metropolitan Administration place an emphasis on increasing upper secondary school retention and making education relevant to students' lives even if they join the workforce instead of attending upper secondary school.

Wat Pathumwanaram School (WPS) is a public kindergarten through ninth grade institution on the grounds of a temple in the commercial district of Bangkok. Despite its location in one Thailand's most expensive neighborhoods, many of the school's approximately 700 students are from economically disadvantaged backgrounds. WPS is home to an educational garden that uses hydroponics, a method of highly efficient agriculture that replaces soil with nutrient-rich water. The school uses garden produce as a source of income, but its educational use prior to the project was limited.

The hydroponic garden has the potential to serve as a resource for hands-on education to increase the effectiveness of teaching. Further, it could spur students' interest and attendance in school. The goal of the project was to create content for an educational fair that would use posters and hands-on hydroponics activities to reinforce topics taught in the WPS curriculum. The team also sought to improve the educational and economic utility of the garden by proposing various technical improvements.

METHODS

To meet its goals, the team accomplished five objectives:

- **Determine effective hands-on activities for WPS students**
- **Determine topics for the educational fair that will be useful to students after they leave WPS**
- **Determine methods to increase the sustainability of the WPS hydroponics club**
- **Determine possible improvements to the garden in coordination with WPS**
- **Determine if possible improvements are safe to implement in WPS's garden**

The majority of the team's investigation took place in sponsor meetings and informal interviews. The team learned of the garden's history and the school's goals and needs from teachers, WPS administrators, students, and a Bangkok school board member. Communication with hydroponics experts, including the man that built WPS's garden, was also an important aspect of the project. Informal interviews with these professionals illuminated issues relevant to hydroponics in Thailand that were not made apparent in sources written by Westerners.

Direct observation of the garden allowed the team to diagnose technical problems. Before proposing improvements that carried a risk of backfiring and hurting the garden, the team performed a trial on a small patch of morning glory plants to demonstrate the harmlessness of the changes.

FINDINGS

- *Creative activities and competitive games were effective hands-on learning techniques to teach WPS students multiple subjects. The team's experience with these activities produced guiding principles for the development of the educational fair content.*

The varied hands-on activities that the team led with the hydroponics club members appeared to create an effective educational experience and increase students' interest in hydroponics. The team developed guiding principles for the design of hands-on activities at WPS.

- *Appropriate topics to cover in the fair were: "Nutrition and Health," "Biology and Hydroponics" and "Hydroponics in Careers and at Home."*

The booth topics were chosen because research showed that they held utility in everyday life as well as in school and academics. The booths were designed to reinforce concepts taught in the WPS curriculum with hands-on activities and posters. "Hydroponics in Careers and at Home" was designed to also promote hobby hydroponics to parents.

- *Hands-on lessons in the garden gave the club members a chance to develop and exercise critical thinking skills. This appeared to strengthen their enthusiasm and ability to manage the garden.*

The club members' enthusiasm increased as judged by their improved attendance and involvement in activities. The team feared, however, that this increased enthusiasm and interest would wane after the departure of the team and the graduation of the club's current members.

- *Establishing student leadership and regular meetings in the club appeared to increase its sustainability.*

Prior to the project the hydroponics club was disorganized and somewhat unfocused. The team believes that it increased the club's stability and contributed to its sustainability.

- *Proposed changes to the garden that carried a significant risk of harming the plants included: changing the nutrient solution and using an organic pesticide. Safe changes included: cleaning the growing trays between plant cycles, shielding the system from the sun and improving insect netting.*

With the advice of experts, the team identified various changes that it believed would improve the garden. Determining which changes carried a risk to the garden allowed the team to design a trial to test their safety.

- *The trial showed there were no negative results from: covering the reservoir buckets, sheathing the circulation tubes, cleaning the system between plant cycles and using a different nutrient solution. The trial also showed that these changes improved the overall health of the plants.*

The trial plants were not harmed by the team's proposed changed. In fact, measurements showed that they grew about 1.4 times faster than a comparison group tended with WPS's standard methods.

RECOMMENDATIONS

To further increase the educational effectiveness of the garden program and club, the team created these recommendations for WPS:

To use the garden educationally:

- Begin utilizing the garden in teaching many subjects.

To promote the sustainability of the hydroponics club:

1. Create regularity in the students' schedules by continuing regular weekly meetings.
2. Allow the club members to be involved in all aspects of the creation of hydroponics booths at future educational fairs.
3. Create a "Hydroponics at WPS" website to get information out to the entire community.

To improve the hydroponic gardens at WPS:

1. Repair the existing problems of the garden.
2. Before implementing further changes to the garden, test them in a trial similar to that conducted by the team.
3. Investigate varied vertical garden designs and implement those that fit into the arrangement of the rooftop garden being built on the new building.

The team feels that the full realization of the garden's educational potential represents a small step in Thailand's economic and social development. The team members were glad to have the opportunity to participate in this project and have high hopes for WPS's garden program.

CONTRIBUTIONS

NEAL ANDERSON

Neal Anderson through this project had proven himself to be a dynamic team member. Reserved with his words, he has strong leadership abilities. The team often turned to Neal for advice. Not only was he involved in most aspects of the writing and editing process of the report, he was also very involved in many aspects of the fieldwork. For the report, although most everyone in the team contributed to the writing of the Introduction section, he took the responsibility of doing the major editing and re-writing of the document, to ensure proper flow and content. He also contributed in the writing and the editing process of the Background section, as well as, in the writing of the Methodology. He also contributed to the analysis section and helped in the writing and editing of the Conclusion section. When it comes to fieldwork, he helped with the poster designs for the fair. He compiled the material necessary for the Biology poster. In the running of the garden trial, Neal took most of the daily measurements, participated in the transplanting of seeds, and helped with compiling data. He also drew schematics of vertical Hydroponic designs, and presented them to Khun Songyos. For the Homemade hydroponic system, he drew schematic drawings and put the model for the fair together. He participated in the design of hands-on activities for the Hydroponic Club meetings. Neal also participated in determining potential interview questions. His key role in sponsor and advisor meetings was to ensure that the meetings ran smoothly and efficiently. He was also the leader in preparing the agendas and the presentations for these meetings.

SAYAMOL "PLOY" CHANKAJORN

Sayamol "Ploy" Chankajorn although soft-spoken, proved to have some of the most brilliant ideas for the team's approach to solving problems. The team often turned to Ploy for advice pertaining to the Thai culture and nature, and she was always very willing to explain the way things are and the reasons why. She was a key player in much of the fieldwork, although she did not participate much in writing of the report. For the report, Ploy, helped with the writing of the Methodology, as well as the Analysis and Abstract. In fieldwork, she took it upon herself to design two of the three fair booth posters. She put together the material for the "Nutrition and

Health" and "Biology" posters, she also created the money management game that was used as an activity in a hydroponic club meeting. In the garden trial she helped with the preparation for the trial, by helping clean the entire system. She also helped in the transplanting of the seedlings, and was a great help in communicating with the expert Khun Songyos and the experts at Wesco. For Hydroponic meetings, she helped to design interesting hands-on activities, and offered insight as to what Thai students may be interested in. She helped relay to the students the team's goals for the trial. Ploy helped to teach the students different aspects of hydroponics, and encouraged them to observe and respond through the hands-on activities that were used to teach the Hydroponics club members. She interviewed, in both formal and informal settings, the different teachers to acquire information that was necessary for the team's progress. In the sponsor and advisor meetings, although she was shy to participate she did so anyway, and was a huge help in translating much of the material that was needed for the meetings into Thai, such as the agendas and the presentations. This helped the team to better relay the information to the sponsor.

IVANA INDRUH

Ivana helped in both the writing and editing of the report and much of the fieldwork. Her determined personality and outgoing nature made it easy to approach her and discuss work that needed to be done and ask her to help with anything either pertaining to the report or the fieldwork. For the report, she helped with the writing of the Introduction, Background, Methodology, Analysis and the Abstract sections. She also wrote most of the Conclusions and Recommendations chapter. Ivana helped with the editing process of the Methodology, the Analysis, and the Conclusion. For the fieldwork, she prepared the Hydroponic brochure materials as the team felt that she is the most knowledgeable in hydroponics and hydroponic systems. She helped to design the poster for the hydroponic fair booth. In the Garden trial, she suggested the approach of the trial by helping to identify key aspects the team should focus on. Ivana helped to prepare the system for the trial by participating in the cleaning of the system. She helped in transplanting the seedlings into the nutrient bath. She was responsible for the compilation of data and the creation of the comparison charts. Her outgoing nature proved to be beneficial in that she was able to communicate with Erik Biksa, a hydroponic expert from the United States who was a beneficial source in helping to determine the best approach without

losing much of the team's very limited time. She drew schematics for the vertical Hydroponic designs and presented those drawing to Khun Songyos. Due to the language barrier she was limited in communications with the club members, but she helped in the design of hands on activities. For the Sponsor and Advisor meetings, she was the one to describe the hydroponic approach and the way things work in the garden, and on a few occasions she prepared the presentations for the meetings.

ZAKKAI KAUFFMAN-ROGOFF

Zakkai Kauffman-Rogoff through this project proved to be one of the stronger writers. Because of this Zak took it upon himself to do a fair share of the writing. For the report, he helped to write the Introduction, Background, Methodology, Analysis, Executive Summary, and the Abstract chapters. He also helped to edit the Introduction, Background, and analysis chapters. After much of the Background had been ripped apart in the first submission of the draft, he took it upon himself to singlehandedly rework the entire chapter to ensure that all parts flow smoothly and that the proper information was in the section. He also took it upon himself to write the executive summary. For the fieldwork, he helped with the transplanting of the seedlings into the nutrient bed. He also helped to design hands-on activities that could be used with the Hydroponics Club. He was also helpful in determining the questions the team needed answered from the school officials, the sponsors, and the advisors. He was often the direct contact between the sponsor and the team.

THEERAYA "PAN" KRISADAPHONG

Theeraya "Pan" Krisadaphong was a dynamic team member. She was very helpful in all aspects of the project, including both the writing and the fieldwork. Although there was less participation in the report aspects of the project, without her help in the field work parts of this project, the team would not have had the time to complete all that they set out to do. Pan wrote sections of the Methodology, Analysis, and the Abstract. For fieldwork, she designed the Nutrition and Health posters, and helped to make the Hydroponic poster look more professional. Pan helped in preparing for the trial, by helping to sterilize the system. She also helped in the transplanting of the seedlings. Pan's knowledge of Chemistry and Hydroponics proved to be very beneficial when it came to mixing the nutrient solution. She knew what parts of the nutrient

solution were missing from the ingredients and she went to the supplier to get those parts. She also singlehandedly mixed the solution that was used for the trial. With the materials gathered, Pan created the Hydroponics brochure in both English and Thai. She was very comfortable in communicating in both formal and informal interviews with the teachers and the sponsor as well as the expert Khun Songyos. This was beneficial for when the team had questions and was seeking advice on how to progress with the project. She ran most of the club meetings very effectively and the student responded very well to her. Pan helped in designing hands on activities as well as implementing those activities with the Hydroponic club. She explained to the Hydroponic club members the goals of the trial and helped in teaching the different aspects of hydroponics. For the sponsor and advisor meetings, she helped in the translation of the agendas and the presentations which allowed the sponsor to be more comfortable in the meetings and to fully understand what the team was proposing.

BRIANNA LEDWITH

Brianna Ledwith has a very happy and enthusiastic personality. These traits helped the team on a magnitude of occasions, despite the lack of morale at times, to move forward and continue the work. Brianna helped in all aspects of the project, both in the writing and the fieldwork. She helped with the writing of the Introduction, Background, Methodology, Analysis, and Abstract sections. Brianna has strong grammar and writing skills and was the key person in the editing of the report. She helped to edit the Methodology, Analysis, and the Conclusion. For the fieldwork, Brianna helped in the garden trial by helping to prepare the system for the trial. She helped to sterilize all parts of the system with boiling water. When the team had a hard time in identifying the pest causing issues in the garden, she spent hours searching the internet to find reliable sources. After a long search she not only identified the pest in the garden, but also found an organic solution that would rid the garden of the pests. In addition Brianna went to all the club meetings and helped in the designing of the hands-on activities that were used to educate the Hydroponic club. For the sponsor and advisor meetings, Brianna took it upon herself to put together the minutes after each meeting, which often required time out of work to be completed to the demands of the sponsor and advisors.

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INTRODUCTION

As a modernizing country, Thailand is boosting its economy by placing an emphasis on educating its workforce. To accomplish this, the Thai Ministry of Education and the Royal Family have devotedly reformed and improved the education system over the past forty years. Free public education is offered for children from grades kindergarten to twelve but many Thai students only complete the compulsory portion, which ends after grade nine. Reforms in 2002 suggest that the Ministry of Education is also unsatisfied with the effectiveness of pedagogical methods and curriculum content in Thailand. These reforms aim to improve the thinking skills of students and incorporate learning that will be relevant to them after they leave school and enter the workforce, even if they do not complete all twelve years of school. Wat Pathumwanaram School (WPS) in Bangkok has been chosen as a model kindergarten through ninth grade school by Her Royal Highness Princess Maha Chakri Sirindhorn for its success in teaching the compulsory portion of public education. Recently, the school developed a rooftop educational garden that uses hydroponics, or water-based soilless gardening. WPS hopes to use its garden program to create hands-on learning environments to enrich education and teach concepts of self-sufficiency that students will put to use in their careers and daily lives.

Though the garden has potential for improvement, its successes have encouraged WPS to further implement hands-on education and increase the practical application of the lessons it offers. The school has been interested in incorporating the garden into more aspects of its curriculum. However, school administrators are aware that reworking a curriculum is a daunting task and that the creation of hands-on activities is particularly time-consuming. Taking small steps to utilize the garden academically, WPS showed interest in creating a two-day student fair to further complement an existing yearly exhibition for parents. The exhibition was used in the past to promote hydroponic technologies for use in the home, rather than furthering the education of students. The new education fair sought to use the garden as a resource for activities that supplement and enrich topics taught to students in traditional classes, as well as introduce new concepts that are particularly relevant to hydroponics.

The primary goal of this project was to use hydroponics as a teaching aid for hands-on activities conveying topics valuable to students after they leave school. The secondary goal was to improve the productivity and teaching utility of the garden. To successfully accomplish these

goals, the team developed a series of objectives, focusing on assessment of the school's needs, physical improvement of the garden and the production of fair and exhibition material. In this process, the team cooperated with a hydroponics club, made up of WPS students in grades seven and eight. Because of the relatively short duration of the team's stay in Bangkok, the involvement of the club was crucial to the continuing improvement of the garden program. The team sought to strengthen the club and increase its involvement in activities utilizing the garden, including the educational fair and adult exhibition.

This IQP has potential to improve the experience and outcome of education for the students of WPS. The team believes that this project represents a small step in Thailand's development of a highly educated population with the means to reach increased economic success. As WPS is a model school, the team also hopes that other schools may learn from the project, and follow WPS's lead by integrating more hands-on activities into their curricula.

BACKGROUND

This background frames the context of education in Thailand and explains the current role of the hydroponic garden at Wat Pathumwanaram School (WPS). Next, it describes advantages and disadvantages of hydroponics. It then makes a case for the potential of the garden to meet the educational goals of the Thai government, HRH Princess Maha Chakri Sirindhorn (the school's patron) and the school itself. Lastly, it describes the physical state of the garden and WPS's wishes for the project.

THE STRUGGLES AND PROMISE OF THE THAI EDUCATION SYSTEM

Thailand's primary and secondary education system may be its single greatest asset in its development from third-world poverty. Education is integral to producing the human capital that is the fuel of development in today's increasingly skill-based global economy. A writer for the Philippine Daily Inquirer put it well: "Education is the only viable long term – and lasting – solution to poverty. The quality of education a child gets directly relates to opportunities that will open up for him later in life" (Apostol, 2004). However, the Thai system is faced with poor retention of students in higher grades and problems with applicability of learning after students leave school. Thai national and local programs exist to address these problems.

In 1932 a constitutional monarchy replaced the system of absolute rule in Thailand, bringing with it the beginnings of public education. After seventy years of development, the Thai education system is organized similarly to the American one. Students enter the system at age six and pass through one grade per year if they meet expectations. As illustrated in Figure 1, pre-university education is divided into four levels: pre-primary, primary, lower secondary and upper secondary. The state provides all of these except pre-primary for free and requires students to attend primary and lower secondary education, allowing them to leave school after they have completed the equivalent of the American grade nine.

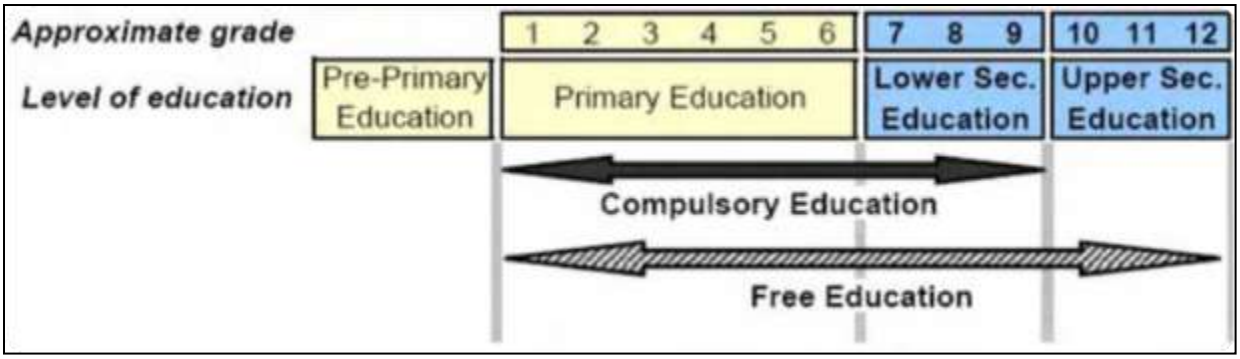

FIGURE 1: GRAPHICAL REPRESENTATION OF THE THAI EDUCATION SYSTEM (UNESCO BANGKOK, 2008)

As shown in Table 1, almost half of Thai students leave school after they have completed their mandatory education. These students do not attend upper secondary school, which is equivalent to the American grades ten through twelve. Many factors contribute to this high drop-out rate, not least of which is the demand for labor by minors from Thai households. Despite the increase in earning potential that comes with an upper secondary school diploma, many Thais cannot afford to stay out of the job market once they have reached working age and can legally leave school. The higher rate of secondary school attendance by females visible in Table 1 is likely caused at least partly by women's lack of access to jobs that do not require extensive education but are traditionally male. At 82.3%, Bangkok's secondary school attendance rate is higher than that of the rest of the country (UNESCO Bangkok, 2008). However, many of WPS's students come from low-income families, a background that makes them more likely to leave school after grade nine.

	Total	Male	Female
Secondary	78.1%	74.8%	81.5%
Lower Secondary (mandatory)	97.7%	95.9%	99.6%
Upper Secondary (optional)	59.4%	54.6%	64.5%

TABLE 1: THAI ENROLMENT IN SECONDARY EDUCATION (UNESCO BANGKOK, 2008)

HRH King Rama IX's 2002 National Education Plan is the Thai government's primary initiative to retain students into upper secondary education. However, the plan recognizes that

since roughly 43% of Thailand's workforce is agricultural laborers, many students will not stay in school despite its efforts (CIA, 2009). Because of this, the plan also pushes schools to offer an education that has applicability after students leave school, even if they do so after grade nine. The plan also strengthens vocational training programs as an alternative to traditional upper secondary education, targeting those who are interested in skilled professions but cannot afford to pursue an academic educational track. The vocational programs teach subjects ranging from agriculture and business to tourism. The government of Thailand sees the National Education plan as a means to stimulate a knowledge-based economy (UNESCO Bangkok, 2008) and speed the country's economic and social development.

Development in science, technology, engineering and mathematics (STEM) education has proved a path to economic prosperity for nearby countries such as Japan and South Korea, and it has the potential to be a powerful force for development in Thailand. Thai education focuses heavily on rote learning through memorization and repetition. One study (Paris, Yambor, & Packard, 1998) shows that while these methods are effective at creating certain technical skills, they do not foster the creativity and problem solving abilities that are important in many STEM disciplines. On the local level, the Bangkok Metropolitan Administration (BMA) is attempting to address this issue through its Smart Schools initiative. The initiative seeks, among other things, to improve the critical thinking and analysis skills of Bangkokian students. The BMA believes that these skills are necessary to increase the technical knowledge of Thais in the long run, making them more likely to enter and succeed in STEM fields (Bangkok Metropolitan Administration, 2005).

It is fortunate that the Thai national and Bangkok local governments are so engaged in the development of education programs. HRH the king's National Education Plan and the BMA's Smart Schools Initiative represent an involvement of government that can be instrumental in the development of public education systems in developing countries (Garrovillas, 2005).

HRH the king is not the only royal family member involved in education. HRH Princess Maha Chakri Sirindhorn, or Pra Thep (meaning "Princess Angel"), is revered by the Thai populace for her programs with education development. Her office sponsors WPS and uses it as a model for other K-9 institutions around the country. HRH the princesses' office is interested in

promoting concepts of self-sufficiency in Thai students and adults, both through education and other programs (Her Royal Highness Princess Maha Chakri Sirindhorn's Personal Affairs Division, 2007). HRH the princess has also expressed interest in increasing the amount of nutrition and healthy lifestyle lessons in Thai curricula. Despite the continuing reduction of traditional causes of poor nutritional health, such as poverty, the nutritional health of Thai children is currently on the decline. Some experts believe that poor eating, unhealthy lifestyle choices and lack of information about nutrition are contributing greatly to the problem (Ekachai, 2010). HRH the princess has focused on home gardening as a way to promote the understanding of the appropriate role of food and reverse the current trend towards a less healthy population (Her Royal Highness Princess Maha Chakri Sirindhorn's Personal Affairs Division, 2007).

WAT PATHUMWANARAM SCHOOL AND ITS HYDROPONIC GARDEN PROGRAM

The primary and lower secondary school on the grounds of the Buddhist temple Wat Pathumwanaram has existed since before Thai education was nationalized in 1932. Nestled in a rice-growing area of Bangkok that later became the city's bustling commercial district, WPS has persisted through hard times with a clever and resourceful administration, famously raising money by giving tours to foreigners. In 2007 HRH Princess Maha Chakri Sirindhorn discovered the school on a walk through its neighborhood and, impressed, decided to take patronage over it (May, 2007). The school joins other projects in her effort to improve Thai primary education and skill development, particularly in science. As an urban school, it is an exception to the generally rural focus of her projects (Her Royal Highness Princess Maha Chakri Sirindhorn's Personal Affairs Division, 2007).

WPS hosts 700 students in grades kindergarten through nine. The school administration has used HRH the princess's resources to grow and improve its facilities, making it one of the most technologically advanced primary and lower secondary schools in the country (May, 2007). With help from HRH the princess's palace staff, the school built a simple hydroponic garden on the roof of one of its buildings in 2007. Because of the success of the garden so far, the school also began the construction of a second hydroponic garden on the roof of a new building. When it is ready in the 2010-2011 academic year, this new garden will feature more advanced technology for use in the school's vocational programs.

ADVANTAGES AND DISADVANTAGES OF HYDROPONICS AS AN EDUCATIONAL RESOURCE

Various factors make a hydroponic garden an appropriate resource for educational use at an urban school. Hydroponics can be sustained throughout the whole year almost anywhere, provided appropriate climate control is available. Hydroponic gardening has no requirement for arable land, so it can thrive at schools in cities or other non-fertile areas. Because of its controlled environment, pest and weed control is far easier than with a traditional garden. The nutrient solution provides the plants with ideal mixtures of nutrients, so hydroponic plants grow faster than the same species in soil. This means that educational demonstrations of plant life cycles take less time and are more accessible to students (Resh, 1995). If balanced correctly, the nutrient solution produces higher yields per surface area than traditional agriculture, potentially accommodating educational experiences for more students. These increases in yield can be very dramatic; some plants, such as potatoes and rice, produce as much as five times more by weight per unit area (Jones, 1983).

A sometimes prohibitive disadvantage of hydroponics is high startup cost. Materials such as growing trays, pumps, usable water and specialized nutrients are required. In some cases, refrigeration systems or lights are needed to successfully operate hydroponic systems in hot climates or indoors. Hydroponics also requires care of the nutrient solution to maintain the correct concentrations, which sometimes requires specific skills and knowledge (summarized in Appendix I: Technical Information on Hydroponics). WPS' royal sponsorship and access to hydroponics experts has helped it to largely overcome these common hurdles to the implementation of hydroponics.

THE ROYAL SPONSORSHIP AND UNCERTAIN ROLE OF HYDROPONICS AT WPS

The creation of WPS' garden was inspired by the hydroponic system at HRH Maha Chakri Sirindhorn's palace, Sra Prathum. Khun Chawalee Amatyakul, the palace's majordomo, initiated the project at WPS with the help of her friend, hydroponics expert Songyos Yongsiri of Prathomchai Hydro Tech Co., Ltd, who earlier helped develop the palace garden. When she began the project in 2007, Khun Chawalee sought to spread awareness of hydroponic technology

and create an educational resource for the school. Because of its high start-up costs, hydroponics is rarely featured in the classrooms of countries of Thailand's level of economic development (S. Komarakul, January-February 2010).

The existing garden's role at WPS is still very much in development. The garden supplies fresh vegetables at lunch time for the school children, many of whom come from the neighboring slum. In a meeting with WPS faculty, it was pointed out that the garden was weakly constructed, without professional-quality materials or workmanship and with its full educational potential yet to be reached. WPS wishes to broadly integrate the garden into its curriculum as a teaching aid for as many subjects as possible. The school recognizes, however, that this process will take time.

In past years the garden had been used as a demonstration of hydroponic technology to parents of the school body in a yearly exhibition. The exhibition sought to spread awareness of hydroponics and encourage families to supplement their income and nutrition with household systems. However, between exhibitions only a handful of students and one teacher, Aajaan Lalita, worked with the garden, meeting weekly as the school's hydroponics club. Day-to-day care of the system was carried out by the school's custodial staff. In its initial investigation, the team located some printed materials detailing exercises to teach students use of the garden, but was unable to find evidence that the garden had been used as a hands-on tool to teach academic subjects.

THE POTENTIAL OF WPS'S HYDROPONIC GARDEN TO MEET MYRIAD EDUCATIONAL GOALS

WPS and the project team see the garden program as a means to move the school towards meeting the goals of the National Education Plan and Bangkok Smart Schools initiative. By providing an exciting tactile environment for a variety of hands-on activities, the garden has the potential to increase student involvement and interest in school, leading to better attendance and higher interest in education. As a venue for discovery learning, it has the potential to help students develop critical thinking and analysis skills. Hands-on activities in the garden also have the potential to reinforce concepts taught in rote learning settings during traditional classes.

Because some scientific knowledge of plants is required to run WPS' garden, it has particular utility in reinforcing classroom lessons about nutrition, biology and other sciences.

Research in first-world education shows that hands-on education, in which students have a chance to experience content directly and physically instead of solely through explanations, are often far more effective at fostering critical thinking skills than rote learning (Paris et al., 1998). In combination, hands-on and rote learning are effective at producing individuals with knowledge and the skills to apply it. In addition, discovery learning, in which students are allowed to guide themselves through a learning process, has been shown to increase students' creative abilities. Hands-on and guided discovery learning techniques are becoming ever more prevalent. Being part of this trend is likely to increase the economic value of a Thai education in a world where employees increasingly compete for jobs based on their knowledge. These modern educational techniques also have the potential to increase students' interest and excitement about school, as they have been shown to generally be more enjoyable to students (Paris et al., 1998). In all students, especially in younger children, interest and engagement are just as important as the advantages an education provides in motivating students to learning and intellectual achievement (Harris, 2000).

The production of marketable produce by school gardens creates an opportunity to teach the concepts of self-sufficiency that HRH the princess wishes to convey to the populace. WPS' students are based in a city, so few of them will enter a career in any form of agriculture. However, student involvement in the sale of vegetables can be used as a venue for business and entrepreneurship training. An execution of business education through hydroponics can be seen in a 2008 IQP which developed a system to grow vegetables for sale in a business and management training program in Northern Thailand (von Roth, Schreiber, Rotatori, & Ortiz, 2009).

Because it does not require arable soil, hydroponics is likely the only way for HRH the princess to bring her rural home gardening initiatives to the urban poor. As long as the cost is kept below prohibitive levels, it is feasible for Bangkok families to start small hydroponic systems in their homes, potentially supplementing their income or nutrition.

As a program with potential for hands-on education in business, science and other fields in a poor but rapidly developing country, hydroponics at WPS has the opportunity to be an

important force in the lives of many young Thais. It is possible that development in the garden and the curriculum that accompanies it will produce replicable hands-on activities for implementation in other Thai schools, though these activities would need to be compatible with soil gardening to be applicable to poorer schools. Any increase in hands-on teaching in Thailand could be helpful in the achievement of greater student engagement and quality education, which have the potential to lead Thai students into more attendance in upper secondary education and to speed the country's economic development.

THE GARDEN IN USE AT WPS

WPS's garden is located on the roof of a minor school building, but is easily accessible to students attending classes in the main building. It is ten meters by six meters and contains approximately ten growing trays at any time, each holding between 100 and 400 plants. Because of WPS's location in Bangkok's commercial district, the garden is shaded at some times of day by skyscrapers.

The system at WPS uses a method of hydroponic culture known as the deep flow technique (DFT) or deep root floating technique (DRFT). As visible in Figure 2, plants are mounted in small blocks of foam, with stalks growing from the top and roots growing through the bottom. These foam pieces plug holes in Styrofoam trays.

FIGURE 2: HYDROPONIC CABBAGE GROWING IN A SPONGE BLOCK

The trays are suspended above a flowing bath of nutrient solution about three to five centimeters deep. Parts of each plant's root structure dangle in the water. The water is oxygenated by a circulation system, in which it is pumped from a reservoir bucket, through small spouts which spray water through the air, into the growing tray and then into the bucket once more. Shallower nutrient solution allows for superior aeration, but a shallow design was not chosen for WPS's garden because it was believed that a small amount of water would heat up very quickly in the Thai climate, potentially harming the plants. The spouts and the growing tray with nutrient solution can be seen in Figure 3.

FIGURE 3: PLASTIC TRAY AND WATER SPOUTS USED IN WPS'S GARDEN

DFT can be used in nearly any setting; systems like WPS's provide great operating efficiency and are inexpensive to operate compared to other hydroponic systems. This system also provides for both plant and root visibility, which is good for educational purposes and can be used for a large variety of plants. To see the roots, students need only to lift the plants from their Styrofoam trays. Doing so briefly does not harm the plants.

Because of its school-appropriate design and ease of maintenance, the system at WPS has great potential as an educational resource. Unfortunately, the system is in need of improvement and its full potential is yet to be reached. The team's efforts to improve the garden are explained in the Methods, Analysis and Conclusions and Recommendations chapters, as well as various appendices.

USING A CLUB AND AN EDUCATIONAL FAIR AS VENUES FOR LEARNING

Upon the team's arrival in Thailand, WPS proposed that the team put the garden to use through the involvement of hydroponics and the hydroponics club in a school-wide educational fair. This year, the fair took place concurrent with the yearly adult-focused exhibition, but focused on educating students in classroom subjects, using hydroponics and other novel tools as a teaching aid. To involve the student body in the process of running the fair, the school requested that the team work with the hydroponics club to develop the educational fair content, also hoping that the club would be strengthened in the process.

The team believed that a two-day fair was an appropriate venue for the first integration of the hydroponic garden into large-scale hands-on educational activities. The large number of students that are present at fairs allows for exposure and advertisement. However, no one student spends very long with any given fair booth, so activities can be short and relatively simple. Since hands-on activities are difficult and time-consuming to create and plan, this was an attractive feature of the educational fair medium.

METHODS

The goals of the project were to improve the hydroponic garden in use at Wat Pathumwanaram School (WPS) and teach topics useful for WPS students after they leave school utilizing hydroponics as a teaching aid. To meet these goals the following objectives were completed:

- Determine effective hands-on activities for WPS students
- Determine topics for the educational fair that will be useful to students after they leave WPS
- Determine methods to increase the sustainability of the WPS hydroponics club
- Determine possible improvements to the garden in coordination with WPS
- Determine if possible improvements are safe to implement in WPS's garden

DETERMINE EFFECTIVE HANDS-ON ACTIVITIES FOR WPS STUDENTS

Through a review of literature the team understood that there are a variety of hands-on activities that could be used to enhance the material being taught at the educational fair including colorful posters, games and other interactive activities. To decide which activities to use, the team met with a variety of WPS teachers and students.

The team began this process by consulting Aajaan Lalita (*"aajaan*" is Thai for "teacher"). She is the instructor for both the hydroponics club and hydroponics class. She has been teaching these classes for a number of years and has a strong knowledge base on how to teach students at WPS. In informal interviews the team asked Aajaan Lalita how her students learn. The team focused on her teaching methods and the students' reactions to what she teaches. The team inquired whether these methods were successful in the past and how to incorporate them into a fair setting.

The team also met with English Aajaans Mathew Willingham and James Allman. Both are native English speakers teaching in Thailand for only a year. They teach multiple grade levels and have experience working with students for short periods of time. The team questioned the teachers on how to keep students engaged in the lesson being taught. The team focused on how the teachers convey material in English to different grade levels.

Bi-weekly meetings with the school's hydroponics club provided a venue for testing and refining fair booth content. The team used this opportunity to practice designing hands-on activities, assigning them to the club, and then receiving its feedback through informal group conversations. Since the team did not know the level of communication between students and faculty at WPS, direct interactions with the club were important for providing reliable information about the opinions of students. Conversations with the club were also crucial for gauging the level of reasoning skills and background knowledge that could be expected of students at WPS. The Chulalongkorn University team members also provided insight from their experiences growing up in the Thai educational system.

DETERMINE TOPICS FOR THE EDUCATIONAL FAIR THAT WILL BE USEFUL TO STUDENTS AFTER THEY LEAVE WPS

The team dedicated time in the beginning and throughout the project to assessing the educational needs of students at WPS to determine what content was appropriate to convey in the educational fair. This assessment consisted mainly of communication through meetings, emails and informal conversations, supplemented by Internet research on issues in Thai education and society. In early meetings with school officials it became clear that WPS had already decided that the hydroponics section of the educational fair would consist of three booths. Each booth would be based around a set of tables and various educational visual aids covered by a tent.

The team's most frequent contact at the school was Aajaan Patraporn. She was still working part-time at the school, aiding in the development of new vocational programs that involved hydroponics but were not within the scope of the educational fair. She provided a rich body of knowledge on the school and the hydroponics program itself, having been involved in the garden since its beginning. Because of her experience and status, the team took her opinions to be important in decision processes. Most of the team's conversations with Aajaan Patraporn took place in the formal setting of sponsor meetings and relied on a translator. She was interested in integrating the garden into the curriculum as widely as possible across multiple subject areas as a general educational resource. Early in the project she listed a variety of ideas of topics for hands-on lessons utilizing the garden. These ideas included biology, business and entrepreneurship, art, English, cooking and nutrition.

During the project, the new director that would succeed Aajaan Patraporn was attending training and was very rarely available at the school. Aajaan Wirat, one of WPS's two deputy directors, had temporarily assumed many of his duties. Meetings with Aajaan Wirat took the same form as those with Aajaan Patraporn. He provided information about the physical layout and logistics of the fair but had few specific suggestions regarding content. The team also carried out brief consultations with Aajaan Wirat on numerous occasions, as he was very accessible and able to provide the most up-to-date information on the school's planning of the fair.

The team's consultations regarding the project went beyond the school itself to involve Dr. Supalak Komarakul, a senior school board member with interest and involvement in WPS. Dr. Supalak was present at all sponsor meetings and was in frequent email contact with the team throughout the project. As the only sponsor with a fluent command of English, she often acted as interpreter during meetings. Dr. Supalak took responsibility for providing the team with an insider's view of the way decisions are made within the school and the Bangkok School System. The team also consulted with Dr. Supalak regarding the history of the garden, learning from her of its beginnings and the educational purpose intended for it by Khun Chawalee, the majordomo of the HRH the princess's palace that originally set the project in motion.

In choosing content for the booths, the team referred to demographic data and literature regarding youth in Thailand, as well as the content of recent educational reforms by the Ministry of Education and the Bangkok Metropolitan Administration. These sources illuminated general issues in Thai society and the ways of addressing them that were being pursued by those at the top of Thai education. Information on careers and economic trends in Thailand was particularly important in determining the utility of topics covered after students leave school.

The school asked the team to develop the content for the adult exhibition booth that would follow the model of the past two annual exhibitions. This project ran parallel to the development of the student fair booths, but was much smaller. In developing the content for the booth, the team discussed its purpose with school officials and distinguished it from the educational booths. The team discussed the fair booth content informally with Khun Songyos, the expert that designed WPS's garden and helped with the hydroponics project in HRH Princess Maha Chakri Sirindhorn palace. Khun Songyos gave valuable input on his experiences in

educating Thai people in the use of hydroponics. He also gave ideas on how best to promote hydroponics to the community.

DETERMINE METHODS TO INCREASE THE SUSTAINABILITY OF THE WPS HYDROPONICS CLUB

In order to ensure the long term success of the project the team placed a focus on the improvement of the WPS hydroponics club. The club would be able to continue the work the team began in the garden and continue the educational fair in years to come. To accomplish this, the project team met weekly for eight weeks with the club in an informal after-school setting, without the presence of Aajaan Lalita, the teacher in charge of the club.

To determine appropriate methods to sustain the club the team asked club members what they do in the garden and why they are involved with the school's hydroponics club. Meetings with the club were organized around hands-on activities either in the garden or a classroom. The team observed the students' behavior and participation in these activities to determine the members' level of enthusiasm about the club and the garden program. In addition, the team asked students about the past and future activities of the club. The team observed that the students were much less open and talkative when in the presence of a teacher or in any formal setting.

The team asked Aajaan Lalita for her thoughts on how to improve the club and further promote hydroponics in the school. She was invited to the later meetings so the club would be comfortable with the presence of a teacher. This way the club could get used to working with a teacher and still be able to give input to the maintenance of the garden and the development of the club.

DETERMINE POSSIBLE IMPROVEMENTS TO THE GARDEN IN COORDINATION WITH WPS

To improve the garden in use at WPS the team determined which problems needed to be addressed in collaboration with school faculty. The team met with school faculty to determine

which problems were the most important and should be addressed. The team made additional observations and advised the school on other improvements that could be made using data collected from literature and expert advice.

To determine which problems the school wanted addressed the team met with Aajaans Patraporn and Lalita. Aajaan Patraporn, despite not working directly with the garden, had insight of the school's long term hopes for the garden. She had the insight to advise the team on the purpose of the garden and how it is used in the school curriculum. Aajaan Lalita, on the other hand, works directly with the garden. She is in charge of its maintenance and the school courses that relate to the garden. Aajaan Lalita was knowledgeable on how hydroponics works and knew what aspects of the garden could be improved upon. She was also aware of the amount of work each improvement would require and was able to prioritize the needed improvements for the team. Although at first she was not willing to give input, as she did not want to deter the team from making progress, after a few formal meetings she expressed her concerns with the team's desired approach. After more communication she felt better about the team's approach as, she realized, it would not cause any immediate changes to be made to the garden as a whole.

To build upon the recommendations from Aajaan Lalita and Aajaan Patraporn the team investigated the garden personally. The team was able to observe a number of problems, specifically nutrient deficiencies. The causes of these problems were identified by consulting the book Hydroponic Food Production by Dr. Howard M. Resh. This information was later confirmed by multiple hydroponics experts. One expert the team consulted was Songyos Yongsiri of Prathomchai Hydro Tech Ltd., Co. He was a good source as he had local experience and was familiar with hydroponics under the Thai conditions. He was familiar with the DRFT system at WPS, because he was the provider and the installer of the system. With many years of experience he was not only able to verify the cause of the problems the team observed but was able to suggest possible solutions. Khun Songyos advised the team on the proper EC values that should be observed, as well as possible insect repellants to use in the garden. A second expert in the field of hydroponics the team was able to contact was Erik Biksa. He is an expert form the United States who works for the hydroponics company, Advanced Nutrients. The team sought advice from him in order to validate and make a stronger case for the suggestions that Khun Songyos made. Erik Biksa also offered sources of information on pest control in hydroponic

gardens. After receiving much information on how to approach the problems pertaining to hydroponics specifically, the team spoke with Aajaan Pongtharin, a faculty member of Botany Department at Chulalongkorn University. He advised the team in the identification of the pest in the garden as well as potential solutions to eliminate the problem. His recommendations were also validated by Erik Biksa and Khun Songyos.

DETERMINE IF POSSIBLE IMPROVEMENTS ARE SAFE TO IMPLEMENT IN WPS'S GARDEN

In order to improve the existing garden and determine a long term solution to the garden's existing problems, the project team conducted a controlled trial. In order to do this efficiently and effectively, the team had to first determine the problems of the garden and the overall improvements that could be made to it. The team listed the problems to be addressed in the trial; these included general plant health, unstable pH levels, nutrient saturation levels, algae and fungi growth, aeration of the nutrient bath, and insects.

The team performed the trial with 400 morning glory plants, the plant that the sponsor decided would be the plant for the trial due to its relatively short, twenty-five day plant cycle as well as its high demand. The trial began at the seedling stage and went through the plants' harvest. The trial batch of 200 seedlings was under the care of the project team and the comparison batch of 200 seedlings was under the care of the garden's caretaker Khun Sakorn. At the seedling stage, the seedlings were placed into their individual sponges and were kept in moist and dark conditions for two days. Once sprouting occurred, the plants were transplanted into the nutrient filled beds. Both the comparison and the trial plants were under the same conditions for the seedling stage; however, once transplanted, the team controlled every aspect of the plant cycle during the trial, implementing any necessary changes along the way. In order to do this successfully the team was provided with a table completely equipped with a DRFT system, same as the system being used in the rest of the garden. The trial plants were grown in separate nutrient beds than the comparison plants. This was done so that the solution could be independently controlled.

Before beginning the trial, the team sterilized the equipment that would be used. This was done to prevent any contamination of the nutrient solution. Every part was cleaned including the beds, the pumps, all the tubing, and any part of the system which the nutrient solution would come in direct contact with. The sterilization process was done by washing every part, listed above, in boiled water, scrubbing off any undesired residue, and then rinsing the parts with boiling water again. After the system was sterilized the parts were put back in place (Resh, 1995).

There were two solution parameters that were adjusted for the trial; these included the nutrient solution itself as well as the nutrient solution concentration. The solution was adjusted to include more nutrient parts including monoammonium phosphate, nick-spray, and manganese – EDTA. This was done to solve malnutrition problems that were witnessed during observations. The concentration levels were decreased because evidence in expert literature suggests that oversaturation of nutrient solution could be just as damaging as under saturation of nutrient solution, to the plant's health and its ability to grow. Advice of experts suggested that the saturation, measured by the EC, should be maintained at EC levels between 1.4 and 1.9, instead of the 2.5 to 4.0 levels that were being used by the school. Not only would lowering saturation levels be beneficial for optimum plant yield, but it would also lower the amount of nutrient solution that is needed, decreasing the overall cost required for the nutrient solution (Yongsiri, 2010; Biksa, 2010). The saturation and solution parts adjustments were made specific to the morning glory plants that were grown for the trial.

To determine the success of the trial the team measured four parameters throughout the trial. From the fourth day of the trial, when the plants were transplanted into the nutrient solution, the team began measuring the height of the stalks, the length of the roots, as well as the EC levels. Despite not being regulated by the team, the pH level was measured as well to see its relationship to the solution's EC level. The collected data was placed into an Excel spreadsheet and can be viewed in Appendix II: Garden Trial Data.

The height of the morning glory plant stalks was measured to determine the growth rate of the trial versus the comparison group. It was measured through the means of a random sample. Each day three different plants in each group were measured and their average was calculated. This process was repeated every day that the measurements were taken. The team believed that a

simple random sample was the best choice for gathering data as there were too many plants to individually measure each one. The root lengths were also measured through the same process. The measurements were taken to determine if the root length was specifically related to the plant growth.

The EC levels were measured to ensure that the levels did not decrease or increase through the course of the trial. In the case that they did, the measurements allowed the team warning of the change so that they could adjust the EC level accordingly. The measurement was taken daily with an electronic EC meter, which also provided the team with the temperature of the nutrient solution. The pH levels were monitored to see if the new solution would cause the pH to reach an unsafe level.

Additional observations were made daily to check for any evidence of pests. In order to avoid any insect problems, the team sprayed the plants with a tobacco solution as suggested by WPS. The team initially mixed an alcohol-tobacco solution which could have been harmful to the plants and so it was only applied twice. The alcohol solution was replaced with a boiled water and tobacco solution. This was because the alcohol free solution would have the same repelling effects with less damage to the plants.

Throughout the trial the team performed regular system checks. In these checks, the team made sure that the pumps were functioning and that there were no clogs within the system. Also the water levels were checked, both in the beds as well as in the reservoir. This was to ensure that proper aeration was being created and that the water levels were not at unsafe values. By monitoring the temperature within the reservoirs the team would be able to note if the water levels were getting too low. A decrease in water level would cause an increase in the water temperature.

The data gave a reasonable comparison of the successes of the trial. The team expected to see an increase in the growth of the plants, as well as healthier plants due to the new nutrient solution formulation. The team determined that the trial would be successful if any of the following outcomes took place:

- The number of plants lost in the trial group is less than the number of plants lost in the comparison group.

- The plants in the trial group grow at a faster rate than the plants in the comparison group.
- The plants in the trial group are larger and healthier than the plants in the comparison group.
- The complete cycle of growth, from seedling to harvest, of the trial group is shorter than that of the comparison group.

When the experiment was completed the team analyzed which changes could be implemented effectively into the full garden and recommended them to the school. They can be viewed in detail in the Conclusions and Recommendations chapter of this report.

ANALYSIS

This chapter describes the major findings of the project and provides supporting data. The team determined improvements to the school's existing hydroponic system. In addition, the team determined appropriate techniques for teaching hands-on lessons with hydroponics as a teaching aid.

EFFECTIVE HANDS-ON TEACHING METHODS

CREATIVE ACTIVITIES AND COMPETITIVE GAMES WERE EFFECTIVE HANDS-ON LEARNING TECHNIQUES TO TEACH WPS STUDENTS MULTIPLE SUBJECTS. THE TEAM'S EXPERIENCE WITH THESE ACTIVITIES PRODUCED GUIDING PRINCIPLES FOR THE DEVELOPMENT OF THE EDUCATIONAL FAIR CONTENT.

Hands-on activities and events that the team led at the school appeared to benefit students educationally; some had the added benefit of raising awareness about the garden program at WPS. The discoveries the team made while implementing them assisted the development of the educational fair booths (Hendry & Pranis, 1995; U.S. Congress. Office of Technology Assessment, 1988). When interviewing teachers regarding the design of more academic activities, the team found that most Thai students, especially those in grades offered by WPS, are particularly engaged by competitive games. English teachers, Matthew Willingham and James Allman, shared their experiences designing games in which students worked creatively in teams to write or brainstorm in English. Due to the limited English abilities of most WPS students, the teachers had only implemented simple games. Aajaans Matt and James added that prizes for winners give the students motivation to actively participate in the activity and recommended them for future games.

Based on the recommendations of the English teachers, the team conducted a series of competitive hands-on educational games with the hydroponics club. These games included analyzing problems in the garden, translating Thai phrases into English, and exploring business concepts. Some games, conducted in Thai, were considerably more complex than those described by the English teachers. In one board game-style activity, the team asked students to perform calculations to determine the most profitable path through a set of boxes representing possible business transactions. The goal of this activity was to give students an engaging way to

practice mathematics, critical thinking and decision-making skills. The students competed in teams to apply mathematics skills and arrive at an answer. Students had varying degrees of success coming up with the correct answer. After the activity, the correct answer was explained to the students to reinforce the concepts they had learned. The team believed this game provided an appropriate level of challenge for the club, based on the concentration the students appeared to put into it.

The informal setting created by this teaching method seemed to harness students' energy rather than quelling it, as the team feared would be the case with rote learning techniques. Games spread across multiple meetings also seemed to be successful at teaching and helping students retain content; the club members applied more correct information as sessions passed. Despite the success of the games, the team noticed many limitations; even though a majority of the students retained the important information, more difficult material was sometimes lost. We believe this happened because we did not take enough care that the material would be reinforced by the curriculum and it lacked context in the students' minds. The competitive nature of the games also allowed cheating. Students often focused on the prize at the end of the game instead of material the team taught. The team attempted to keep the students focused by using multimedia in the games and encouraged fair play by keeping a close watch during games. The time and attention required to watch for cheating represented another limitation of these games.

The team also utilized the garden in two hands-on activities. These exercises were designed to give students a chance to practice observation and critical thinking skills. Students explored the garden and recorded differences between plants and problems with the garden, then regrouped to discuss the causes and effects of these differences. The students seemed to be particularly stimulated by these activities. The team believes that the activities interested the students because they were novel to children primarily used to rote-style learning. Next, as an attempt to include more students in hands-on activities, the team organized a school-wide competition to create a slogan for WPS's hydroponics program. The team chose this activity based on the success of competitive games. It provided hands-on practice with communication and writing skills that the team did not observe elsewhere in the WPS curriculum. For an explanation of the poster and slogan competition, see Appendix III: Poster Slogan Competition. Students from multiple grades created the slogans, which covered many demographics.

Although the slogan contest featured prizes to catch the interest of students, the team found it difficult to get the students involved, and the first few days of the competition resulted in no entries. The team placed posters around the school to advertise the competition, but concluded that spoken advertisement by students would be more effective. The winning slogan was created by a third-grader and roughly translates to "Hydroponic veggies, the soilless food you can plant anywhere and eat every day." WPS also appreciated the completed slogan as a productive byproduct of the competition.

Because the winner was not a club member, the team concluded that the contest had some success in engaging a broader audience than its earlier hands-on activities. However, there was no way for the team to gauge whether the competition had actually improved the communication and writing skills of the students, as the team did not know many of the students involved before the contest and had no baseline for comparison.

Experience organizing these activities led the team to develop guiding principles for the hands-on components of the educational fair. The team realized that it was important to make the activities straightforward and to the point. It was also beneficial to reinforce them with rote-style content and in-depth explanations. Additionally, it was important to ensure that students remained focused and fair in competitive activities. The team also felt it was effective for students to be encouraged by authority figures if they were to be expected to participate in unfamiliar activities. Overall, it was crucial that content taught in hands-on activities striked a balance between being excitingly novel to catch students' interest and being an existing part of the curriculum to ensure that it had grounding and context.

APPLICABLE TOPICS FOR STUDENTS' LIVES

APPROPRIATE TOPICS TO COVER IN THE FAIR WERE: "NUTRITION AND HEALTH," "BIOLOGY AND HYDROPONICS" AND "HYDROPONICS IN CAREERS AND AT HOME."

The team determined that a good way to convey the material suggested by Wat Pathumwanaram School (WPS) faculty was to create three fair booths: "Nutrition and Health", "Biology and Hydroponics", and "Hydroponics in Careers and at Home." Teaching subjects that could be useful to all students regardless of their future plans is important, since it is impossible to know which students would stay in school until being of university age. One of the most

important subjects the sponsor showed interest in is English language. English can help the students in the long run by helping them get farther in the business world after they leave school. Most foreigners in Thailand who do not speak Thai often speak enough English to have basic interactions. Students could have more international interactions in business if they knew English. The team incorporated English into all of the booths so that the students can learn it throughout the entire fair.

All students learn differently and the fair booth material needed to be chosen based on their needs. Based on the recommendations of Aajaans Matthew Willingham and James Allman, and the briefness of students' interaction with each fair booth, the team attempted to design booths with simple and clear material. The need for simplicity was also expressed by Aajaan Lalita and other teachers. However, the team understood from its background research that learning is a long term process and that information given without context and repetition would unlikely be retained by students. To accommodate this, the team worked with teachers to ensure that the material covered in the booths would support information currently being taught in those classes. The team's goal was to reinforce concepts in the Thai curriculum with multimedia and hands-on learning, as opposed to introducing new ones.

NUTRITION AND HEALTH

The topic of "Nutrition and Health" is universal in that a basic knowledge of it benefits everyone, regardless of age or background. The sponsor expressed concern that children had been choosing fast food over healthy food for its convenience and flavor. "During 2004-7, the number of children who regularly consume sodas and junk food [in Thailand] increased 1.8- and 1.5-fold respectively" (Ekachai, 2010). Statistics show that rates of diseases related to bad nutrition are also increasing and children are suffering as a result. The article exemplifies the fact that these trends are caused by misleading advertisements and unhealthy choices, rather than economic circumstances. The team determined it was important to show the children that healthy food can be both inexpensive and delicious (Ekachai, 2010). The team created an activity which gave students knowledge about nutrition concepts. This activity would have the students make their own smoothies and salad dressings. The goal of this activity would require participants to be thoughtful of the ingredients in their food and the origin of those ingredients. The team further

planned to sell the hydroponic vegetables at the booth so the students could taste their newly created salad dressings on a salad grown right at the school. The team also planned to encourage the students to pass what they learned on to their families at home so that the greater community would be informed on nutrition and healthy eating habits. This activity aimed to teach the students the importance of not only eating healthy but also knowing what is in the food they eat. The team emphasized this lesson through a comparison between fast food and home-cooked food. The team hoped that the students would receive the information enthusiastically, but was aware that an understanding of the benefits of good nutrition would be insufficient in making students give up junk food. The team also planned to show students how even in the center of Bangkok, families and communities can use hydroponic and other vegetables to prepare healthy meals at home. By teaching these lessons, information can be used long after the project team leaves Thailand.

BIOLOGY AND HYDROPONICS

"Biology and Hydroponics" was the topic that related most directly to WPS' rooftop garden. Hydroponic systems provide an ideal visual teaching aid for demonstrating basic plant anatomy to the students. The team organized activities for the hydroponics club to run during the fair, including bringing students through the garden and showing them all of the plant parts using specimens growing in the system. The students could point out every part of the plant and could even show the plant roots by lifting the foam trays, in which the plants were suspended. The activities would give the students a more tangible experience that would lead to retention of the information learned regarding plant anatomy and basic biology. The team was concerned that not everyone would be able to understand the activities due to the difficulty of getting the students or teachers to reveal what each class was learning. The team tried to make activities that can be easily modified for each age group; however, it is unsure that every student's needs can be met with this booth. The team aimed to give every student a sense of ownership of the garden. This would potentially ignite interest to join the club or participate in caring for the garden in some way. The team hoped that if the students felt invested in their learning it would increase their desire to stay in school longer and help eliminate the problem of young students ending their education after the ninth grade.

HYDROPONICS IN CAREERS AND AT HOME

The team designed "Hydroponics in Careers and at Home" to promote hydroponics to parents and community members at the fair as well as students. The goal of the booth was to explain the principles behind the day to day operation of a hydroponic system and give participants a hands-on experience of them. The booth was supplemented by a hydroponics brochure, and the team planned to print approximately 100 copies to make available on the day of the fair.

The booth's poster included basic technical information regarding hydroponics, similar to that included in Appendix I: Technical Information on Hydroponics. The team observed that some Thais see hydroponics as unnatural and unhealthy because of its artificial environment. The poster also included paragraphs explaining that hydroponic plants absorb the same nutrients as those grown in soil and are equally, if not more nutritious. The hands-on activity in the booth involved transplanting lettuce seedlings into a small hydroponic system called a SmartBox. This activity is important in the maintenance of a hydroponic garden, so the team felt it was an appropriate introduction to the experience of hydroponics.

The booth also contained an example of an inexpensive hydroponic system that is easy to make at home. The team designed and built this system from easily available local parts with a total cost of 400 Baht (12 US dollars). A simple diagram to explain the creation of this system was included in the brochure. The team hoped that the accessibility of this system would encourage parents and students to try hydroponics in their homes. Images of the homemade hydroponic system can be found in Appendix VI: Design for the Homemade System

EDUCATING THE HYDROPONICS CLUB

HANDS-ON LESSONS IN THE GARDEN GAVE THE CLUB MEMBERS A CHANCE TO DEVELOP AND EXERCISE CRITICAL THINKING SKILLS. THIS APPEARED TO STRENGTHEN THEIR ENTHUSIASM AND ABILITY TO MANAGE THE GARDEN

During and after hands-on lessons with the team, the club members showed considerable knowledge and problem-solving abilities in the context of the garden. The club was able to identify problems in the garden, propose solutions and evaluate the potential positive and negative effects of those solutions. In one instance, students measured high concentration within

the nutrient solution and chose to dilute it with more water. In another example of skillful critical thinking, one of the club members proposed the introduction of new plants with higher market value such as spinach, Italian basil and celery. She determined that the garden could draw a greater profit from sales at the school cooperative, explaining that the cost of hydroponics is relatively high, whereas the current products' sale prices are low. The team believes that the skills and interest demonstrated by the students through these actions will be instrumental in the upkeep of the garden and club once the team has left.

At the beginning of the project, hydroponics club members did not carry much responsibility in the garden; checking on the plants sporadically but rarely making decisions or changes. Some of them had informally assigned chores, but there were no officially assigned roles within the garden. Despite this, the club's performance in hands-on activities with the garden made the team confident that its members were qualified to be responsible for the garden. Elder members of the club were divided into groups to take responsibility for different areas of the garden, including: maintaining the nutrient level measuring the EC values and keeping track of them, making sure that the pH values are in desired ranges, planting the seedlings, transplantation of the seedlings, and the harvesting of the plants. The club members' new positions did not carry rank; the creation of a hierarchical organization of the club was left until later in the project and is described in the section below, Leadership and Regularity in the Hydroponics Club.

Club members expressed interest and enthusiasm in fulfilling the duties of their positions. The team believes that the club members' official responsibilities and experiences with the garden led them to develop a sense of ownership of it. The club members appeared to be aware that their work was important in developing the garden and creating profit through produce sales. The team put in place a system for selecting new students to hold these positions when their original holders graduate. The team fears, however, that this system may degrade into selection of position-holders by a teacher. Without the presence of the team, future club members may be less enthusiastic and teachers may not be capable of motivating them.

The club showed enthusiasm for the materials taught during its eight meetings with the team, but we were unable to ensure the sustainability of our approach. The team feared that after the current members left WPS, the club's feeling of ownership of the garden would be lost. The

team hopes that as new students join the club, existing members will help them develop the same enthusiasm that the team sought to foster.

During the project, the club became accustomed to hands-on learning, critical thinking exercises and official positions. These features of the club did not exist before the involvement of the team, and the team feared they would not be sustained in the future. To mitigate this risk, the team worked with Aajaan Lalita and club members in a series of meetings to ensure that lessons would be replicated in future years. Moreover, the now highly structured club agreed to be responsible for the monthly hydroponics newsletter the team initiated, informing the rest of the school about current events in the club and garden. The team hopes that with the help of the club's advisor, these measures will help hold the club together by encouraging enthusiasm, ownership and responsibility.

LEADERSHIP AND REGULARITY IN THE HYDROPONICS CLUB

ESTABLISHING STUDENT LEADERSHIP AND REGULAR MEETINGS IN THE CLUB APPEARED TO INCREASE ITS SUSTAINABILITY

At the beginning of the project, the team found the club to be somewhat disorganized. It had no formal leadership other than Aajaan Lalita. Meetings happened at inconsistent times and sometimes did not include the attendance of an adult. The team also found that because the hydroponics club members were few and all in grade seven and eight, its ten members had already become close friends. Their rapport was a drawback as well as an asset. It contributed to an informal atmosphere that sometimes made the students unfocused and distracted, but allowed the students to be casual in their learning. To improve the productivity and sustainability of the club and encourage students to take it seriously, the team regularized meetings to 15:30 to 17:00 on Tuesdays and Thursdays, and established a student leadership within the club.

Under the guidance of the team, the club members selected a president, vice president, and secretary to operate the club. The team informed the club of its plans to run traditional elections with nominations and voting. However, the club members arrived at the election with almost unanimous ideas of who would fill each position, even before the team could describe each role. Rather than voting, officers were appointed by consensus. The team and club did not force students to accept positions; the club members that declined a nomination were replaced by

the group's next choice. Though it appeared to be the case, the team could not be sure that a high proportion of the club's members actually endorsed the choice of leadership. There appeared to be a strong social hierarchy within the club members and it is likely that a handful of older students carried disproportionate influence in making decisions about officership before the meeting. Despite these efforts, the club members remained friendly to each other throughout the officer selection process and there was no direct evidence of intimidation.

The club officers agreed to be responsible for holding and running meetings and for incorporating the club in future school-wide activities like the hydroponics fair. The overall direction of the club's activities was decided upon by consensus with the supervision of the team. During discussions of the club's plans, ideas commonly originated with officers and then were discussed by the group. The club chose as its current goals: running the hydroponics fair, advertising the club to gain younger members and maintaining and improving the garden. Based on the team's observations of the club members, we believe they are very capable of creating and running the booths themselves, under the supervision of Aajaan Lalita. The team believes the club's participation in the annual fair will add a source of regularity and focus that will support the sustainability of the club long after the team has left.

RISK AND LOW RISK GARDEN IMPROVEMENTS

PROPOSED CHANGES TO THE GARDEN THAT CARRIED A SIGNIFICANT RISK OF HARMING THE PLANTS INCLUDED: CHANGING THE NUTRIENT SOLUTION AND USING AN ORGANIC PESTICIDE. SAFE CHANGES INCLUDED: CLEANING THE GROWING TRAYS BETWEEN PLANT CYCLES, SHIELDING THE SYSTEM FROM THE SUN AND IMPROVING INSECT NETTING.

Based on the team's assessment of the garden and meetings at the school, we identified a list of proposed changes to the garden. The team selected them based on the opinions of experts and knowledge gleaned from literature. The team had high expectations for the garden improvements, but also wished to be careful with it. In the interest of protecting the existing garden, the team separated the proposed changes into two categories: changes that were not believed to carry a risk of damage to the garden and changes that potentially carried a risk to the garden if improperly implemented.

Once the team divided the proposed changes into these two categories, the team felt confident in recommending the school make the no-risk changes throughout the garden, as their costs in time and money were not estimated to be prohibitive. Aluminum foil and Styrofoam would cost very little and were easily accessible to the school. Cleaning the system with warm water was not difficult and required less than an hour. However, the changes carrying risk could not be recommended without evidence that they would not cause damage to the garden. To create that evidence, the team designed a trial implementation of these changes with a crop of morning glory which can be seen in the final objective: Determine if possible improvements are safe to implement in WPS's garden.

Changes that carried little to no risk included:

1. *Closing openings in the insect netting covering the garden to keep out pests*

Members of WPS had stressed from before the team's arrival in Thailand that insects were a major problem in the garden. The team observed one species of insect in the garden identified, by Chulalongkorn Professor Pongtharin, as a Spring Tail. The team feared that other unidentified insects would plague the garden during other seasons, during which the team would have no opportunity to make species-specific changes. Additionally, the team also observed what appeared to be mouse droppings on the growing trays. Improving the netting was selected as a general partial solution to all pest problems.

2. *Covering nutrient solution reservoir buckets*

The team believed the high water temperatures and sunlight in the garden were contributing to algae growth (Resh, 1995). Algae growth was contributing to malnutrition, and the team feared that it would become an even more serious problem in the hotter, brighter summer months. Covering the solution reservoirs with Styrofoam would prevent sunlight from entering them and pose no harm to the plants.

3. *Sheathing the exposed nutrient solution circulation tubes in aluminum foil*

Though these tubes did not represent as great a surface area of water for heat transfer and light absorption, the team estimated that covering them would be worth the minimal expense.

Similarly to covering the solution reservoirs, sheathing the tubing would inhibit the growth of algae, posing no danger to the plants.

4. *Cleaning the entire system with purified (boiled) water between plant cycles*

Thorough cleaning between every plant cycle is recommended by Resh (Resh, 1995) as well as experts the team consulted (Yongsiri, 2010; Biksa, 2010). The WPS officials told the team in meetings that the system had only been cleaned every two cycles (approximately forty to fifty days). Lack of cleaning contributes to algae growth and damaging chemical impurities in nutrient solution (Resh, 1995).

Changes that carried risk:

1. *Using a nutrient solution recommended by experts*

WPS had little evidence that the nutrient solution in use at the garden was the most effective, so the team sought an alternative formulation. Due to the specific nature of the nutrient solution recommended by experts the team feared the plants could experience malnutrition if not properly mixed.

2. *Using a lower nutrient concentration of the solution, as recommended by experts*

The electrical conductivity (EC) values being used by WPS before the project were higher for a majority of the plants than those recommended by the literature (Resh, 1995). The team verified the appropriate levels with multiple hydroponics experts. Wesco Chemical Limited also explained that the new formulation they helped the team choose required a still lower EC because it nourished the plants more efficiently (Biksa, 2010; Yongsiri, 2010). The team is confident that the lower solution would help the plants but it was questionable if the plants experience malnutrition with the lowered concentration.

3. *Spraying the plants against insects with a tobacco solution*

Though WPS was reluctant to use a chemically-based pesticide, they were interested in trying an organically based solution to ward off insects, as their netting was not proving sufficient and they were frustrated with the presence of insects in the garden. The team chose a tobacco solution because it was recommended by multiple experts as well as multiple gardening internet forums (Biksa, 2010; Yongsiri, 2010). A forum is not necessarily a reliable source, so the team feared that the tobacco solution could have the potential of poisoning the plants. This is why it was

determined that testing the solution on a small scale was vital before implementing it on a large scale into the garden.

TRIAL RESULTS

THE TRIAL SHOWED THERE WERE NO NEGATIVE RESULTS FROM: COVERING THE RESERVOIR BUCKETS, SHEATHING THE CIRCULATION TUBES, CLEANING THE SYSTEM BETWEEN PLANT CYCLES AND USING A DIFFERENT NUTRIENT SOLUTION. THE TRIAL ALSO SHOWED THAT THESE CHANGES IMPROVED THE OVERALL HEALTH OF THE PLANTS.

There were no negative outcomes from the trial, and altogether, the changes improved the yield and health of the plants. The health of the plants was determined by observing the following factors:

- Color of the leaves
- Size of the plant
- Density of the plant within each cup
- Number of plants lost due to malnutrition or pests.

The plants in the trial group were greener, larger in both stalk circumference and height, and had a greater number of stalks per cup than the comparison group plants. The trial group lost fewer plants due to the improved nutrient solution, decreased algae growth, and the organic pesticide. Figure 4 shows that the average stalk length of the trial group of plants grew faster than the control group of plants.

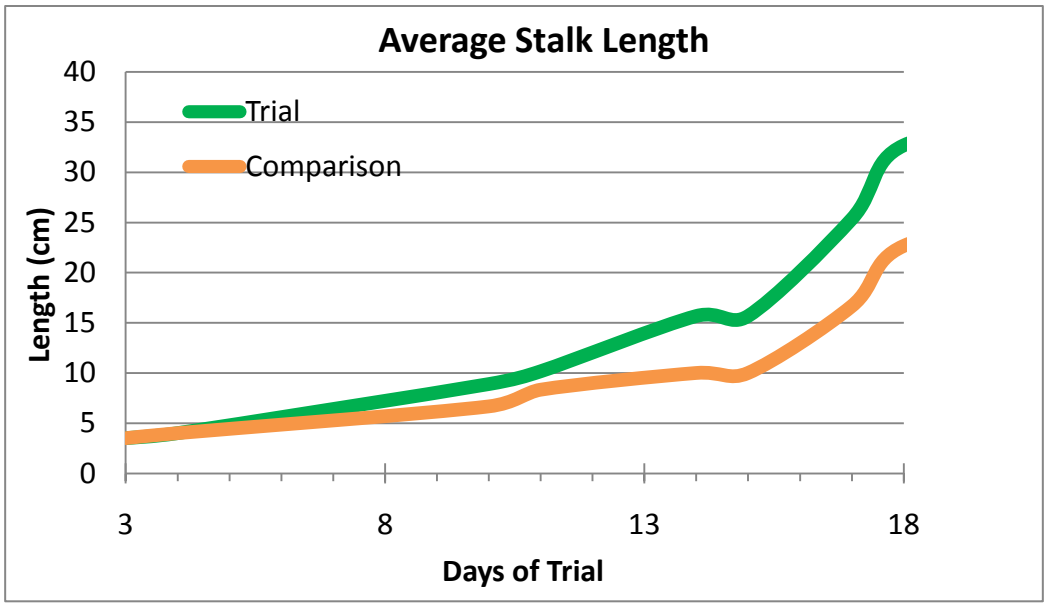

FIGURE 4: AVERAGE STALK LENGTH COMPARISON OVER SEVENTEEN DAYS

In addition, side by side comparison photos show the drastic differences between the heights of the plants (see Figure 6). The first photo shows the plants at ten days old and the second shows them at fifteen days old. More detailed comparison data is available in Appendix II: Garden Trial Data.

FIGURE 5: COMPARISON PLANTS (ON LEFT IN EACH PICTURE) VERSUS TRIAL PLANTS (ON RIGHT IN EACH PICTURE) ON THE TENTH (LEFT) AND FIFTEENTH (RIGHT) DAYS OF THE TRIAL

Additional observations were made by the team throughout the process. The team took note of the differences in algae growth between the comparison and the trial nutrient solutions. A comparison of algae growth between the two groups growing beds can be seen in Figure 6. Algae

can cause not only nutrient deprivation but it can also clog pumps and tubes (Cruickshank, 2009). Covering the nutrient solution helped to reduce the amount of algae growth.

FIGURE 6: COMPARISON OF ALGAE GROWTH, VISIBLE AS BLACK RESIDUE, BETWEEN COMPARISON (LEFT) AND TRIAL (RIGHT) GROWING BEDS

FIGURE 5: PEST FOUND IN THE GARDEN (LEFT) AND THE TOBACCO SOLUTION USED IN THE TRIAL (RIGHT)

In Figure 5, one can see the pest that the team found in the garden as well as the tobacco solution used. The tobacco solution used helped in controlling the pests, as there were no pests visible on the morning glory plants at any time.

Despite these positive results, the team cannot claim that any one of the changes were solely responsible for the outcome. Due to the time restrictions, the team was not able test each variable separately to see which ones had the greatest impact and which ones were unnecessary.

In addition, the team was not able to measure the variables on a daily basis; more comparison points would create an even stronger argument. The team took a simple random sample of three plants from a patch of two hundred to determine the average lengths of the roots and stalks; a larger sample size would also have made a more convincing argument for the increased growth rate of the trial plants. The outcome of the results witnessed can be explained by saying that the team followed the strict guidelines as advised by the hydroponic experts (Khun Songyos and Mr. Erik Biksa), and the background gleaned from the literature written by Dr. Howard M. Resh.

Although the team considered the trial a success, WPS harvested the plants eight days before the typical twenty-five day cycle of the morning glory plants, thereby reducing the number of data points that the team could collect in the final stages of the growth cycle. This also means that the plants were ready for harvest earlier than the plants of the same age in the control group, and the difference in growth would continue to increase if the plants had not been harvested. The effects of high temperatures, large amounts of rain, and different pests were not tested because they trial was only run in the dry season.

Based on the positive results from the trial, the team created a manual to guide WPS in implementing a similar trial to improve the garden as a whole. This manual includes necessary trial information for morning glory plants, as well as other plants in the garden. The information for the other plants came from experts and background literature. The team included this information in the hopes of improving the health and yield of the garden as a whole.

CONCLUSIONS AND RECOMMENDATIONS

The garden's crop yield could be increased by making a few simple changes that will result in healthier plants and an increase in profit. Also, after working closely with WPS students and teachers, the team determined that the garden is not being used to its full educational potential and could be more widely used. We also make recommendations about how to ensure the hydroponics program continues to grow utilizing the hydroponics club already in place at the school.

TEACHING STUDENTS MATERIAL APPLICABLE AFTER THEY LEAVE WPS

In order to educate students in material that is applicable whether or not they continued their education beyond the ninth grade, the team created three fair booths: "Nutrition and Health", "Biology and Hydroponics" and "Hydroponics in Careers and at Home". The students were taught the educational material in the form of competitive games, artistic posters, and slogans, all of which were effective hands on activities for educating the students at WPS. The combination of these topics along with the way the booths were arranged, were designed to allow students to learn a wide variety of material without being overwhelmed with information. Additionally, the hands-on activities would allow students to become more engaged with the subject matter.

RECOMMENDATION FOR USING THE GARDEN TO SUPPLEMENT CURRENT CLASS MATERIAL

BEGIN UTILIZING THE GARDEN IN TEACHING MANY SUBJECTS.

The hydroponic garden is an untapped educational resource at WPS that could be used to teach a variety of topics. Hydroponics could be applied in mathematics in the younger grades in simple ways such as counting different types of plants or calculating the number of plants that could potentially be planted in the garden. In older grades, math can be incorporated in forms of calculating profit margins. English can be incorporated into the garden by labeling all parts of plants as well as the systems in both English and Thai. This activity can be as simple as labeling the parts of the system, such as the words "table" or "nutrient water." This exercise can be

worked up to writing descriptive sentences of what the students see in the garden, or what they would like to see in the garden. For biology, the garden can be used to show the lifecycle of a plant and follow its progress through the entire cycle. The team further recommends that other subjects such as art use the garden as a teaching aid. Through all grades, students could be encouraged to draw a design of a hydroponic system or the plants they in the garden. Hydroponics can allow students to realize that by applying common knowledge with a little bit of science great things are possible, things such as growing plants without the means of soil. Innovation in hands-on applications of learning will allow for the student creativity to prosper and further the educational potential of the lesson.

PROMOTING SUSTAINABILITY OF THE HYDROPONICS PROGRAM AT WAT PATHUMWANARAM SCHOOL

A resource that the school has for promoting the sustainability of hydroponics is the Hydroponics Club. The team realized that once the club members were educated in the hydroponic process, they were able to propose practical ideas to further develop the garden, thereby contributing to the sustainability of hydroponics at WPS. Practical contributions included selecting plants to add into the garden, as well as helping to determine some of the common issues, and potential ways of troubleshooting those problems. In order to secure involvement within the club, a leadership in the form of a student government was established within the club. Additionally, the team encouraged regularity in the meeting times of the club. As a result, there has been an increase in membership as well as regularity in attendance of the students in the club.

RECOMMENDATIONS FOR PROMOTING THE SUSTAINABILITY OF THE HYDROPONICS CLUB

The team has 3 recommendations for promoting the sustainability of the club:

1. Create regularity in the students' schedules by continuing regular weekly meetings.
2. Allow the club members to be involved in all aspects of the hydroponic fair booth creation.

3. Create a "Hydroponics at WPS" website to get information out to the entire community.

CREATE REGULARITY IN THE STUDENTS' SCHEDULES BY CONTINUING REGULAR WEEKLY MEETINGS.

The team recommends that regular meetings, which include hands-on and engaging material, be continued with the club. The material being taught in the club has attracted more members and increased weekly attendance. If interest continues to grow, the hydroponic club could be used as a resource to develop hydroponics booths at future educational fairs and maintain and improve the garden.

ALLOW THE CLUB MEMBERS TO BE INVOLVED IN ALL ASPECTS OF THE CREATION OF HYDROPONICS BOOTHS AT FUTURE EDUCATIONAL FAIRS.

The team recommends that WPS continue the educational fair every year, involving the club both in the creation of educational materials and in the running of the fair booths. The team strongly believes that this can be accomplished without its presence with the involvement and supervision of teachers. The hydroponic club can be responsible for the design and the contents of the hydroponic fair, perhaps in collaboration with other clubs. The club or the teachers could follow the same procedures that the team took. First it was necessary to identify the desired material for the fair. This can be done by asking the school administrators of the school what they would like to see. Following this decision, it is important to develop potential ideas that would be interesting to the students of WPS. Once these ideas were roughly planned, they were again presented to the leadership of WPS, whose input allowed the team to proceed with even more information to fully elaborate on their initial plans. The detailed plans were put into effect and presented at the fair.

By allowing the club members to be in control of every aspect of the fair, they will feel a sense of ownership of the material they are teaching. Also by having students teach the material at the fair, it will encourage student to student interactions and allow for professional communication to be practiced. Communication is essential throughout life in any field of work. By being able to convey educational materials to both fellow classmates and parents, the students who are educating are also practicing a valuable life skill.

CREATE A "HYDROPONICS AT WPS" WEBSITE TO GET INFORMATION OUT TO THE ENTIRE COMMUNITY.

The team also suggests that a common means of sharing information be set up, such as a website geared toward the entire community. This can promote and teach about hydroponics and offer advice and suggestions on how to create cheap and inexpensive systems, such as those suggested by the team which can be viewed in Appendix VI: Design for the Homemade System. This website can be a great means of sharing information throughout the community. It could even include a blog section where people can share their stories, pose questions, and help one another find solutions to the questions.

IMPROVEMENTS TO THE HYDROPONIC GARDEN

The garden itself is also a valuable resource to promote hydroponics within the school. Implementation of variables such as the varied nutrient solution and nutrient concentration posed a risk of backfiring and hurting plants. Because of this they were not immediately implemented in the entire garden. The team conducted a trial to demonstrate the safety of the following changes:

- Covering reservoir buckets
- Insulating circulation tubing with aluminum foil
- Cleaning the system in between plant cycles
- Using a solution mixed specifically for the morning glory plants
- Using an organic pesticide

These changes showed that the growth rate and overall health of the trial plants was greater than the comparison group. On average the trial group showed a 50% increase in the rate of growth. This increased the number of plant life cycles that fit into one year from fourteen cycles to roughly twenty cycles. This greatly increased the amount of plants that could be sold in one year in turn increase profit.

RECOMMENDATIONS FOR IMPROVING THE HYDROPONIC GARDENS AT WPS

Regarding the hydroponic garden at WPS the team has three main recommendations.

1. Repair existing problems in the garden
2. Perform trials similar to the one the team performed to test potential changes before implementing into the entire garden
3. Investigate varied vertical garden designs and choose to implement ones that fit into the arrangement of the new rooftop garden being built in the new building.

REPAIR THE EXISTING PROBLEMS OF THE GARDEN.

These problems include:

- Algae growth in the buckets
- High nutrient concentration
- Non-specialized nutrient solution. (same for all plants)
- Torn netting
- Dirty plant trays

The problems leading to malnutrition of the plants include the spread of algae and a lack of nutrients. The school can start by first implementing the covering of the nutrient solution with Styrofoam to prevent algae growth. This may be enough to prevent malnutrition; however, it may also be the case that the standard nutrient solution is not providing adequate nutrients to the plants. The team was able to run a trial on morning glory plants with a nutrient solution consisting of more nutrients, with results of higher yields and a faster growth rate. However, the team recommends that before implementations are made throughout the entire garden, WPS should contact experts such as Khun Songyos to verify that the solution the team used is also appropriate for the other plants being grown. The team also recommends that, WPS should also confirm with the expert the appropriate EC values for the varying plants, because the team was not able to find the appropriate EC values for all the plants being grown in the hydroponic garden at WPS.

The following is the procedure the team followed in mixing of the nutrient solution for morning glory plants. This procedure also includes the parts of the solution and the appropriate measurements. First the team weighed all the chemicals according to the formulation. Part A of the solution, as seen in Table 1, is mixed into ten liters of water. Following this, Part B of the solution, as seen in Table 2, is mixed into another ten liters of water. Once each solution is

individually mixed, approximately four liters of each solution were mixed into a nutrient bucket. Once the mixed solution, of both parts, had been allowed to sit for approximately an hour, the EC value was measured at a value of 4.00. In order to lower the EC value to the appropriate value, water was added to the solution. As water was gradually added, the EC value was measured until it reached a value of 1.8. Once the desired value was reached, the nutrient solution was introduced to the system.

Part A of the Nutrient Solution	
Compound	***Amount (g)***
Calcium Nitrate (15-0-0)	1000
Iron EDDHA 6%	60

TABLE 1: PART A OF THE NUTRIENT SOLUTION USED IN TRIAL

Part B of the Nutrient Solution	
Compound	***Amount (g)***
Potassium Nitrate	700
Magnesium Sulfate	500
Mono Potassium Phosphate	150
Mono Ammonium Phosphate	100
Nick-Spray	50
Manganese-EDTA	15

TABLE 2: PART B OF THE NUTRIENT SOLUTION USED IN TRIAL

Permanent changes such as fixing the netting, cleaning the systems between transplanting, and covering the nutrient solution buckets can be implemented immediately. The team recommends that WPS fix the netting around the garden before spending further money on pest control. Although it may require a greater amount of money initially, the costs associated with fixing the netting may, in the long run, be less than the costs associated with trying to get rid of bugs and the amount of produce lost due to pests. There are various areas where the netting allows access to the garden to both small insects and rodents. The team suggests that the school search for ways of closing the openings near the ground and the opening between the door frame and the rest of the frame as the primary preventative measure against pests. Another measure the

school can take is to create a solution for spraying against pests. This solution formulation can be found in Appendix X: Garden Handbook.

The systems can be cleaned by taking them apart and rinsing every part of the system that comes in contact with the nutrient solution, with boiling water. The covers for the nutrient solution do not need to be anything extensive, something as simple as a Styrofoam cover can be used to keep the light out of the nutrient solution. These changes will not, to the best of the team's knowledge, have any negative effects on the overall state of the garden; in fact these changes will promote better garden hygiene. Implementing these changes may be enough to decease any additional problems within the garden, such as malnutrition, due to both pests and algae absorption of nutrients.

BEFORE IMPLEMENTING FURTHER CHANGES TO THE GARDEN, TEST THEM IN A TRIAL SIMILAR TO THAT CONDUCTED BY THE TEAM.

In Appendix X: Garden Handbook one can find the Garden Trial Handbook, which the team created based on the data gathered from literature, experts in the field of hydroponics, and the data that was gathered during the trial, which can be seen in Appendix II: Garden Trial Data. This manual was created to assist the staff of WPS in implementing the changes that the team made during the course of the trial, by providing both detailed descriptions of the team's step by step process, and defining the necessary hydroponic vocabulary, therefore familiarizing even those members who may not have thorough knowledge of hydroponics to the subject. The manual includes a detailed explanation of the changes the team implemented and the reasons for implementing those changes. It also includes the results measured during the trial, to show how these changes improved the garden. A section of the manual focuses on the various resources that are required for implementing the garden changes such as necessary building materials, approximate man hours, and the money necessary to implement the recommended changes properly. The final section of the manual was dedicated to describing the detailed step by step methods of implementing the recommended changes.

The team strongly suggests that a similar trial to that found in Appendix X: Garden Handbook be run for the different plants individually before implementations are made into the entire garden. It is important that the school gather all knowledge necessary for the plant they wish to grow. Before starting, WPS should know the safe EC values for the plants optimum

growth, as well as the ideal nutrient solution formulation in comparison to the standard nutrient solution formulation to be used in the trial. This information can be found in literature such as Hydroponic Food Production by Howard M. Resh and experts such as Khun Songyos. Online sources can be used but determining the legitimacy of the source can be difficult. The reason why the team recommends a trial be run for the various plants individually is to make sure that the outcomes on a small scale have positive results before investing large amounts of money and time in an approach that may only be applicable for one type of plant.

INVESTIGATE VARIED VERTICAL GARDEN DESIGNS AND IMPLEMENT THOSE THAT FIT INTO THE ARRANGEMENT OF THE ROOFTOP GARDEN BEING BUILT ON THE NEW BUILDING.

The team also offered some recommendations to Khun Songyos for varying vertical systems, these design drawings can be viewed in Appendix V: Vertical System Designs. The team researched already existing designs and came up with some of their own designs. These designs were presented to Khun Songyos, the expert working on the vertical systems in the new building of WPS. These systems ranged from simple designs to more complicated ones, and the decision for their implementation was left to Khun Songyos.

POST-PROJECT ADDENDUM: EDUCATIONAL FAIR ANALYSIS

Due to the timing of WPS's educational fair, the WPI team members made the decision not to be active participants in running the hydroponics booths. The fair took place outside the allotted project time, limiting the WPI team members' availability. Additionally, through the team's experiences, Thai schoolchildren find foreigners exciting and their presence tends to attract attention. We believed that our presence at the fair booths would distract visitors and the students attempting to run the booths. To encourage self-sufficiency in the hydroponics club members and ensure the sustainability of the booths in future fairs the team gave the club members a high degree of autonomy in running the booths. Limited supervision of club members running the booths was provided by the two CU team members, who were present during much of the fair. As Thais, they were able to attend without distracting the students.

FIGURE 7: STUDENTS ENJOYING HOMEMADE SALADS AT THE "NUTRITION AND HEALTH" BOOTH

During short periods of personal observation the team determined the material for the fair booths was fun and interesting for students. The "Nutrition and Health" booth was particularly popular. The smoothies and "make your own salad dressing" attracted students of all ages (see Figure 7). This allowed club members to talk to other students about health facts and recommend

that students travel to the other hydroponic booths. The "Biology and Hydroponics" booth caught the interest of many older students, who enjoyed using the provided microscopes which can be seen in Figure 8: Students enjoying microscopes. Many of the students asked questions to the club members and many of which read the information on the posters. The "Hydroponics in Career and at Home," booth brought in most of its adult visitors on the second day of the fair in the morning. Many of these people curiously inquired about the homemade hydroponic design, being especially curious about where nutrient solution could be found. The hydroponics brochure developed by the team proved popular as well.

FIGURE 8: STUDENTS ENJOYING MICROSCOPES

In addition to personal observation the team created an optional survey in Thai to be completed by students after they had explored the booths. The results of the survey are visible in Figure 9: Educational fair questionnaire results.

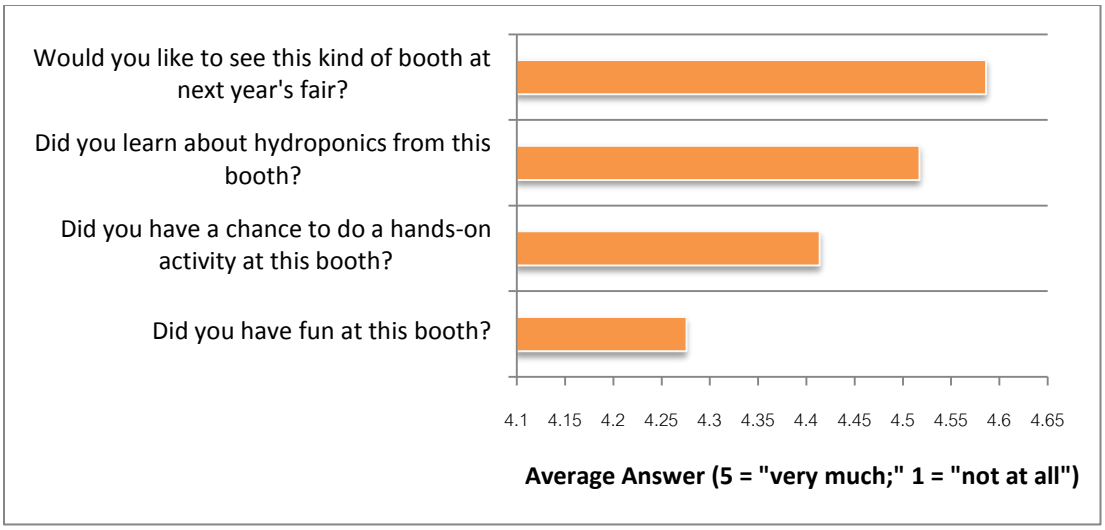

FIGURE 9: EDUCATIONAL FAIR QUESTIONNAIRE RESULTS

The team is very satisfied with the results of the survey, and the survey's positive implications were corroborated by personal observation during the team's brief visits to the fair. Even the question "Did you have fun at this booth?" which had the least positive response, averaged 4.25 out of 5. Unfortunately, some limitations exist for this data-gathering technique. First, it is commonly known that children are unreliable when filling out surveys. Also, the team used smoothies at the "Nutrition and Health" booth as an incentive for students to fill out surveys, so this may have led them to rush. The surveys appear to be frankly filled out upon a brief inspection. Few have the same answer box checked for all questions. Another limitation of the survey was its brevity. The team would have liked to glean more detailed information about the students' feelings regarding the hands-on activities that took place in the booth, but could not find a way to do so without making the questionnaire problematically long and discouraging students from filling it out.

Based on the results of the fair, the team recommends that the school continue student-run hydroponics booths next year with material similar to what was used this year; the booths were very popular with fairgoers and required only minimal supervision by the team. The posters the team created can also be reused, though the team recommends that in the future they be supplemented with simpler, more child-friendly displays to better catch the attention of young fairgoers. The team considers the fair a great success and an important step towards the realization of WPS's hydroponic garden's full potential as an educational resource.

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APPENDICES

APPENDIX I: TECHNICAL INFORMATION ON HYDROPONICS

Hydroponic gardening, also known as soilless gardening, is a method of growing plants using a solution of water and a nutrient mixture instead of soil. The idea of hydroponics may seem new-age, but the concept of growing plants without soil has been known for centuries, as employed from the hanging gardens of Babylon to the floating gardens of the Aztecs in Mexico (Jones, 1983). Soilless gardening has since found useful applications on NASA space missions and crop production on sandy, infertile islands. It has been popularized by hobbyists in cities and other areas where traditional gardening is not possible. Hydroponics' faster growth rate and higher crop yield potential make it desired by many large scale farmers; however, high start-up costs defer many potential investors (Jones, 1983).

PLANT BIOLOGY

All plants require the same basic nutrients. The amount of these nutrients needed varies depending on the species of plant. 90-95% of a plant is made up of three elements: carbon, hydrogen and oxygen. These elements can be found in airborne carbon dioxide and water; therefore, methods of obtaining them are not a major concern for hydroponic systems. The remaining 5-10% of plants' mass is made up of other essential elements, which include nitrogen, potassium, magnesium and phosphorus. In a hydroponic system, these other elements must be mixed with water to create a nutrient solution which nourishes the plants (Jones, 1983).

NUTRIENT SOLUTION

Nutrient solutions are a blend of compounds that cannot be derived from air or water. These blends vary depending on the type and size of the plant. The solutions can be bought commercially as organic materials or chemical mixtures and are difficult to make at home. Using the proper nutrient solutions can cause the plant to grow at much faster rates and result in a higher yield. Traditional, solid fertilizers are not often used in hydroponics because they are

intended to work with soil to provide the needed nutrients and in the absence of soil can harm the plant (Cruickshank, 2009).

The quality of the nutrient solution is measured by its electrical conductivity or "EC." The EC is a measure of the solution's ability to conduct an electrical current through the ions that make it up. For morning glory, the plant most grown in the WPS garden, the EC should fall between 1.0 and 1.2 milliSiemens.

WATER QUALITY

Differences in water quality have also shown significant impacts on plant growth in hydroponic systems. If the source water already has the needed nutrients mixed in, adding more solution can cause over-saturation that can kill the plant. Also, ions such as sulfates or ferrites, which are often present in city water (like that used by WPS), can bind with elements in the nutrient solution, making it useless. Filtering the water before adding it into the hydroponic system can reduce the chance of any contamination (Jones, 1983).

WATER pH LEVEL

The pH (acidity) of the water can greatly affect the growth of a plant. Generally the pH of the nutrient solution should be between 5.5 and 6.5. If the pH is too high or too low the nutrient up-take by the roots can be limited and growth may stop (Cruickshank, 2009). Chemicals can be added to the solution to raise or lower the pH as needed.

WATER TEMPERATURE

Water temperature can also cause significant problems for a plant if not properly regulated. Water temperature should be kept between 16 to 27 degrees centigrade (65 to 80 degrees Fahrenheit). If the water temperature becomes greater than 27 degrees centigrade, root rot may occur due to fungus growth (Cruickshank, 2009). If this happens, chemicals need to be added to kill any fungi and promote new growth.

APPENDIX II: GARDEN TRIAL DATA

AVERAGE STALK LENGTH

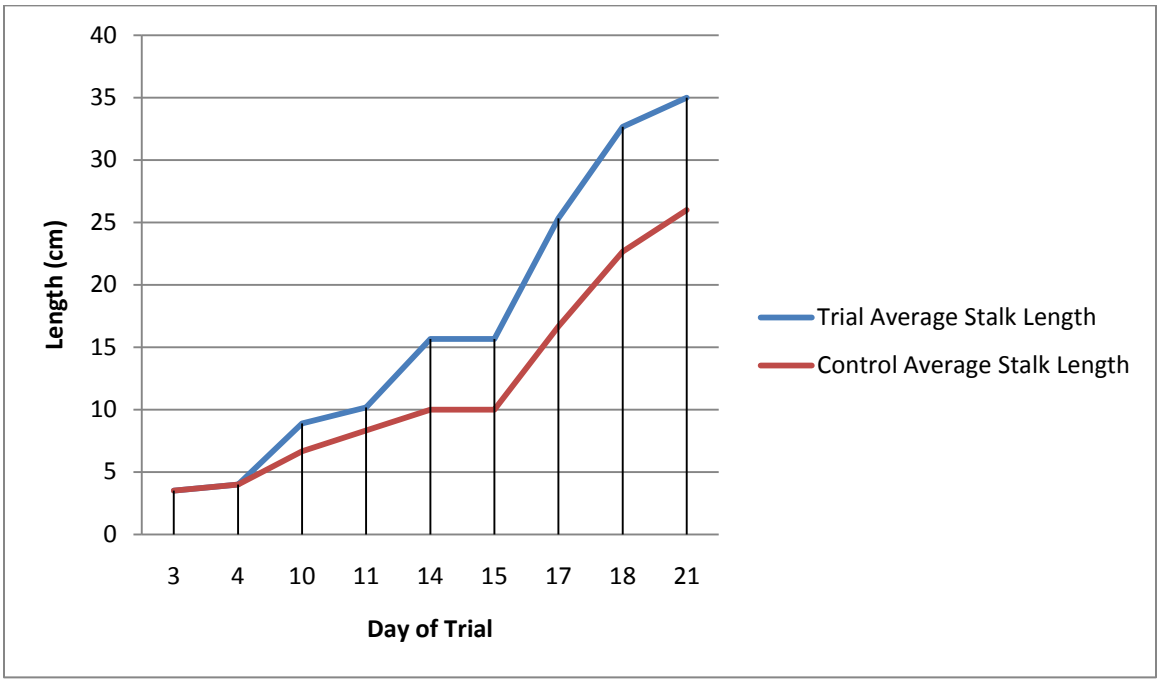


FIGURE 10: AVERAGE STALK LENGTH

This data shows that on average, the trial average stalk length is greater than the control average stalk length.

AVERAGE ROOT LENGTH

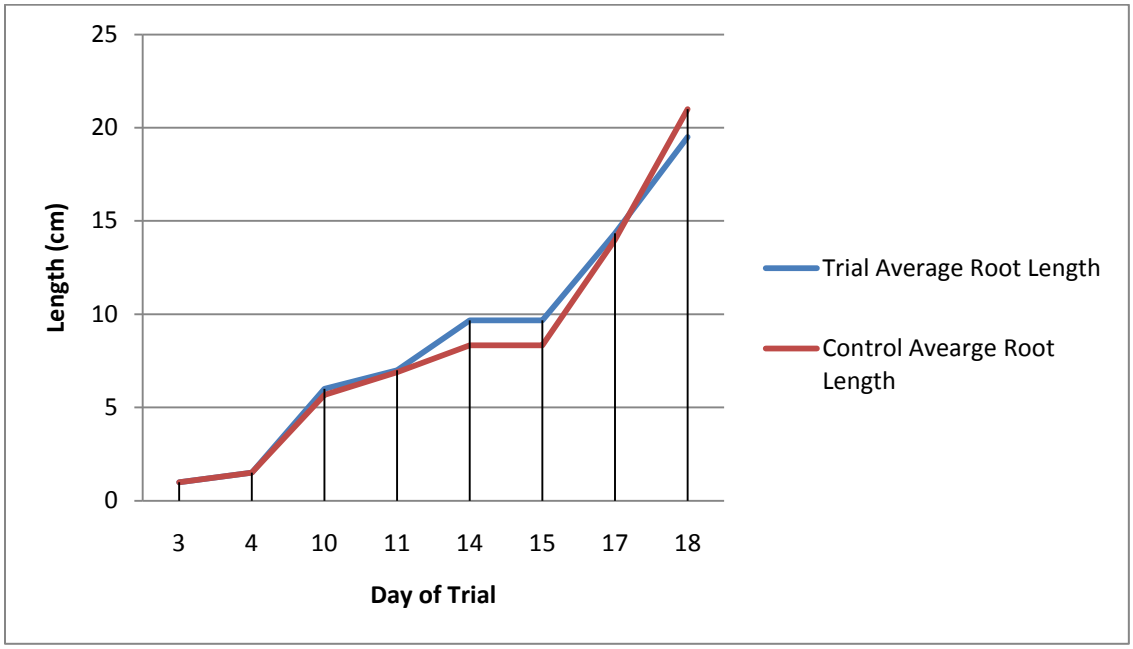


FIGURE 11: AVERAGE ROOT LENGTH

This shows that the control average root length is about the same as the trial average root length up until about day 10 after which the trail average root length appears to be longer, but growing at the same rate. However at about day 15 the rate of the root growth of the control group increases significantly and becomes faster than that of the trial group.

EC COMPARISON

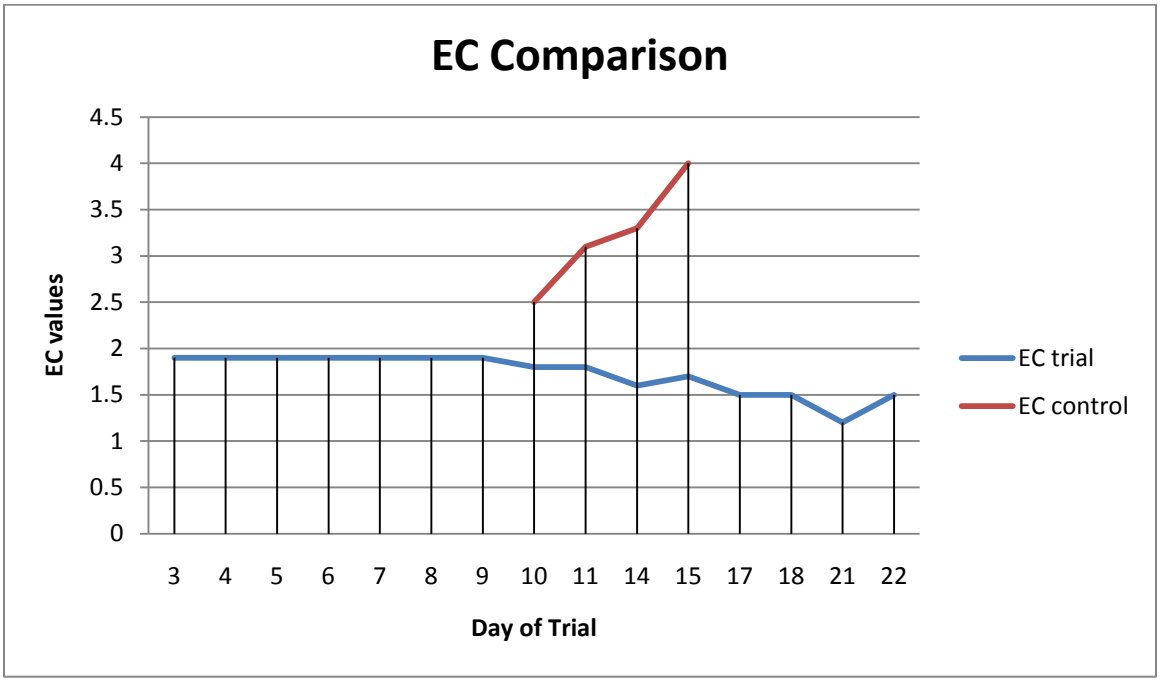


FIGURE 12: EC COMPARISON

The measured EC values for the comparison begin at day 10. Here the EC of the control group is significantly higher than that of the trial group. In fact the EC of the control group gradually rises as that of the trial gradually decreases in value.

PH COMPARISON

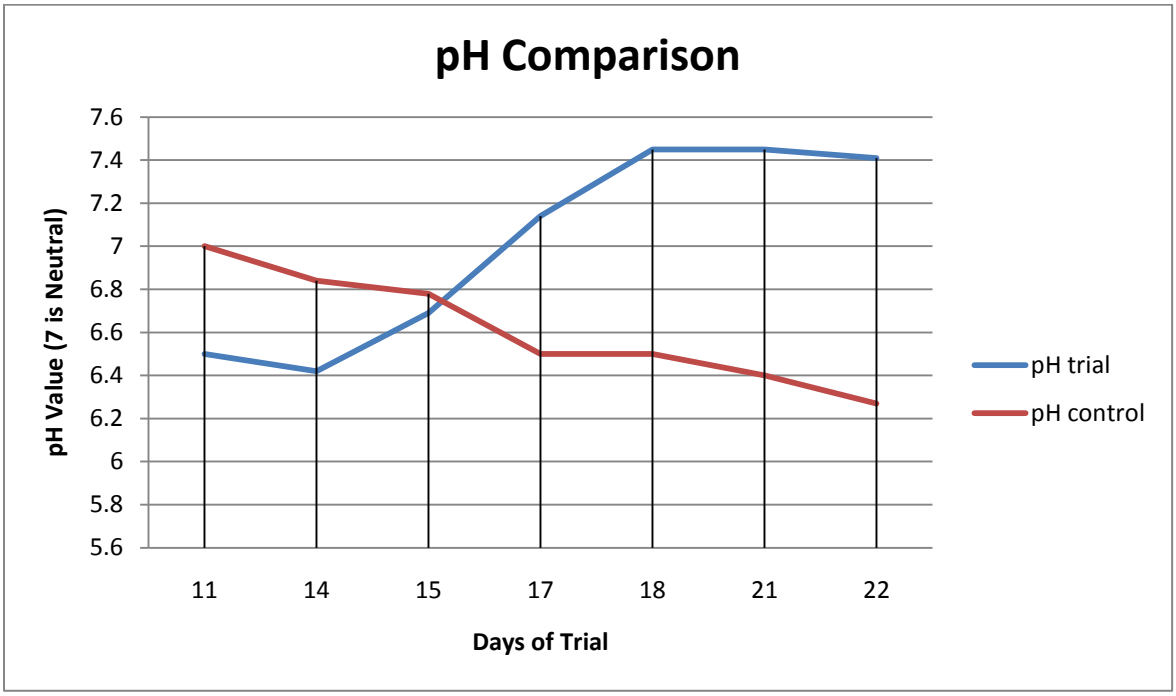


FIGURE 13: pH COMPARISON

Here we see the trend of the pH of the trial group to gradually increase from days 14 through 18 after which it remains at values between 7.5 and 7.4. The trail batch is above recommended values from day 18 to day 22 of the cycle. The control group is showing a good trend in pH. The values are consistently between the values of 7.0 and 6.0 as suggested. This allows for maximum nutrient uptake by the roots.

It is interesting that despite having the conditions for optimum nutrient uptake, the comparison between stalk lengths suggests that the Trial group grew at faster rates. This suggests either that pH is not a contributing factor to the growth of plants or that there were less nutrients or there was a loss of nutrients within the control group.

APPENDIX III: POSTER SLOGAN COMPETITION

Slogan for Hydroponics Competition

In expectation of the 2010 Educational Fair to be held on the 5th and 6th of March 2010, the Hydroponics team is holding a school wide slogan competition. The team of students to come up with the most creative slogan will win a prize of a backpack filled with school supplies, such as notebooks, pens, pencils, markers, etc. The contest begins today the 12th of February and all entries must be submitted to the school office by Thursday 18th of February. The winners will be announced on the following day Friday 19th of February. The slogan will be used to advertise the fair not only within the school but throughout the community!

Details:

1. Form a team of 1-5 students.
2. Design and create a catchy, funny, entertaining slogan for Hydroponics.
3. Contest begins Friday Feb. 12th
4. All entries must be submitted by 14 o'clock to the school office on Thursday Feb 18th
    a. Submitted entries must be in writing with team members' names on the back of the paper.
    b. Identical slogans will not be eligible for prizes, BE CREATIVE!!!

APPENDIX IV: NUTRIENT SOLUTION USED IN TRIAL

Part A of the Nutrient Solution	
Compound	***Amount (g)***
Calcium Nitrate (15-0-0)	1000
Iron EDDHA 6%	60

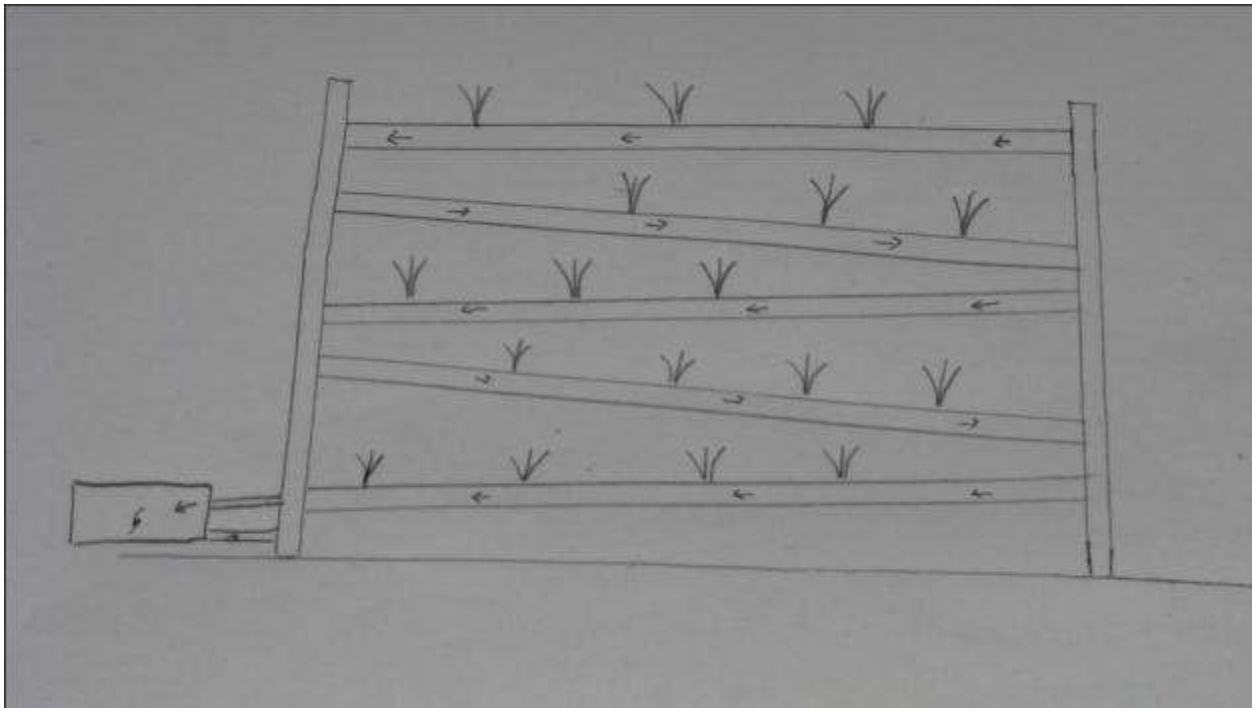
TABLE 2: PART A OF THE NUTRIENT SOLUTION USED IN TRIAL

Part B of the Nutrient Solution	
Compound	***Amount (g)***
Potassium Nitrate	700
Magnesium Sulfate	500
Mono Potassium Phosphate	150
Mono Ammonium Phosphate	100
Nick-Spray	50
Manganese-EDTA	15

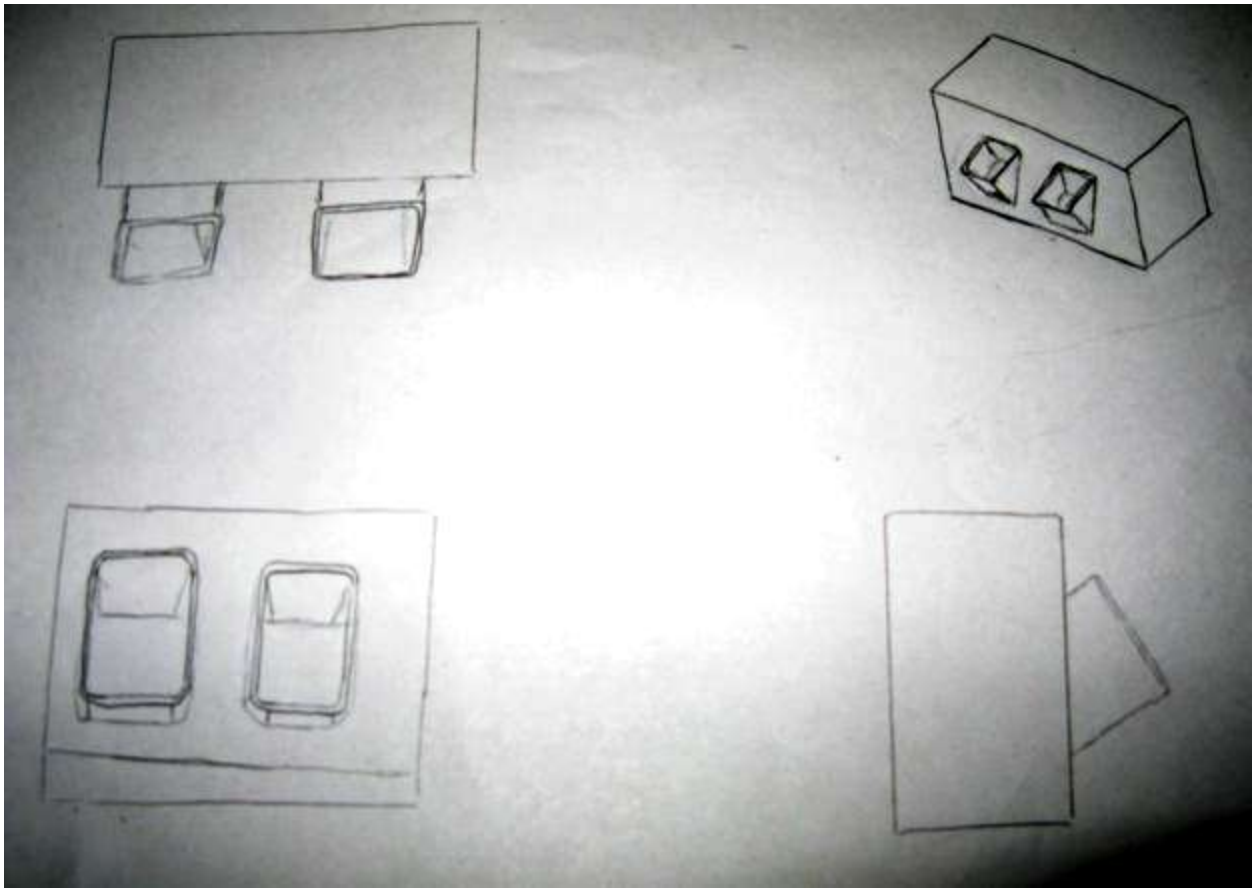
TABLE 3: PART B OF THE NUTRIENT SOLUTION USED IN TRIAL

APPENDIX V: VERTICAL SYSTEM DESIGNS

CASCADE SYSTEM

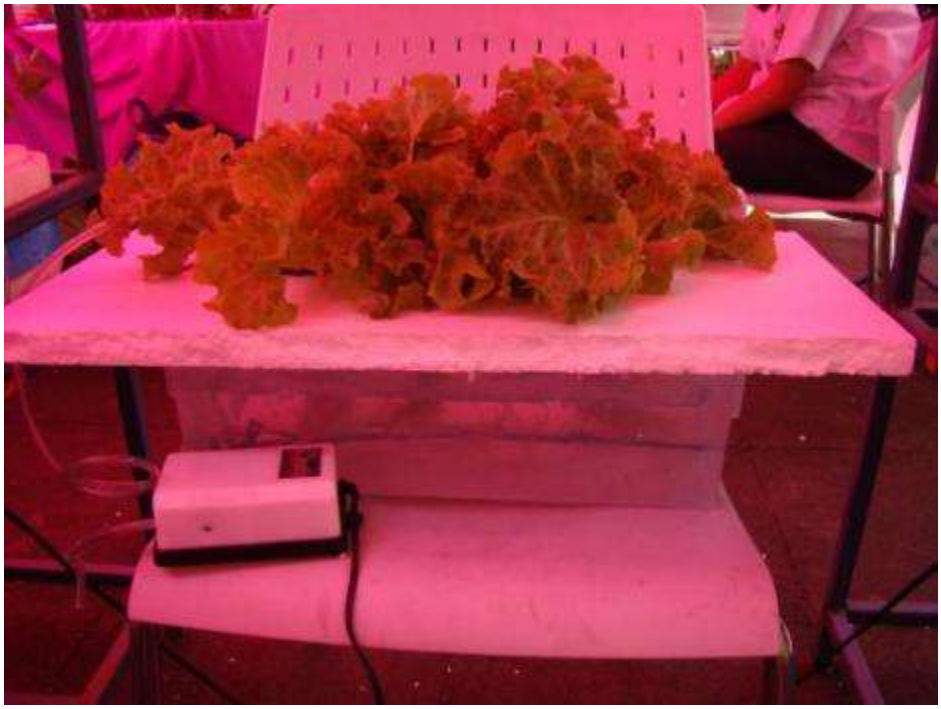


WALL PLANTER BOXES



APPENDIX VI: DESIGN FOR THE HOMEMADE SYSTEM

FULL IMAGE OF THE HOMEMADE HYDROPONIC SYSTEM



AERATION SYSTEM

COST BREAKDOWN OF SYSTEM

Part	**Cost (Baht)**
Aquarium Air Pump	200
Styrofoam	70
Plastic Tray	130
Total	**400**

APPENDIX VII: FAIR POSTERS

BIOLOGY AND HYDROPONICS POSTER

NUTRITION AND HEALTH POSTER

HYDROPONICS IN CAREERS AND AT HOME

ไฮโดรโปนิกส์

HYDROPONICS FOR ADULT

ผักไร้ดิน ปลอดสารพิษ ไฮโดรโปนิกส์

การทำงานของรากพืชที่ปลูกในระบบไฮโดรโพนิกส์

การปลูกพืชโดยไม่ใช้ดิน เป็นการปลูกแบบธรรมชาติหรือไม่

ประโยชน์ของการปลูกผัก Hydroponics ในครัวเรือน

ขั้นตอนปลูกผัก Hydroponics ในระบบ DRFT

ตัวอย่างพืชที่สามารถปลูกโดยใช้ไฮโดรโพนิกส์ได้

APPENDIX VIII: HYDROPONICS BROCHURE

HYDROPONICS BROCHURE FRONT IN THAI

ชมรมไฮโดรโปนิกส์
ณ โรงเรียนวัดปทุมวนาราม

ประโยชน์ของไฮโดรโปนิกส์?

1. ช่วยลดค่าใช้จ่ายในครัวเรือนโดยการปลูกผักรับประทานเอง
2. ส่งเสริมสุขภาพที่ดีเนื่องจากเป็นผักที่ละอาดปลอดภัยจากสารพิษ
3. สามารถใช้ตกแต่งสร้างให้ห้องเรียนน่าอยู่
4. เป็นกิจกรรมของครอบครัวในครอบครัว
5. เป็นงานอดิเรกที่เหลือเหลือและให้ความรู้

ประวัติและความเป็นมาของโรงเรียน

ไฮโดรโปนิกส์

โรงเรียนวัดปทุมวนาราม

ไฮโดรโปนิกส์คืออะไร

ไฮโดรโปนิกส์คือการปลูกพืชโดยไม่ใช้ดิน โดยใช้น้ำซึ่งมีธาตุอาหารพืชละลายออกมาแทน นับเป็นวิธีการใหม่ในการปลูกพืชโดยเฉพาะการปลูกผักและพืชที่ใช้เป็นอาหาร เนื่องจากประหยัดพื้นที่ นอกจากนี้ยังป้องกันศัตรูพืชและโรคพืช และไม่ปนเปื้อนกับสารเคมีต่างๆ จากดิน ทำให้ได้พืชผักที่ละอาดเป็นอาหารทั้งด้านชีวอาหารและภายนอก

HYDROPONICS BROCHURE BACK IN THAI

ปลูกพืชไร้ดินด้วยระบบไฮโดรโปนิกส์

ประโยชน์ของไฮโดรโปนิกส์

ระบบไฮโดรโปนิกส์

Raft System

1.
2. ใช้เวลาในการดูแลน้อย
3.
4.

Aeroponics

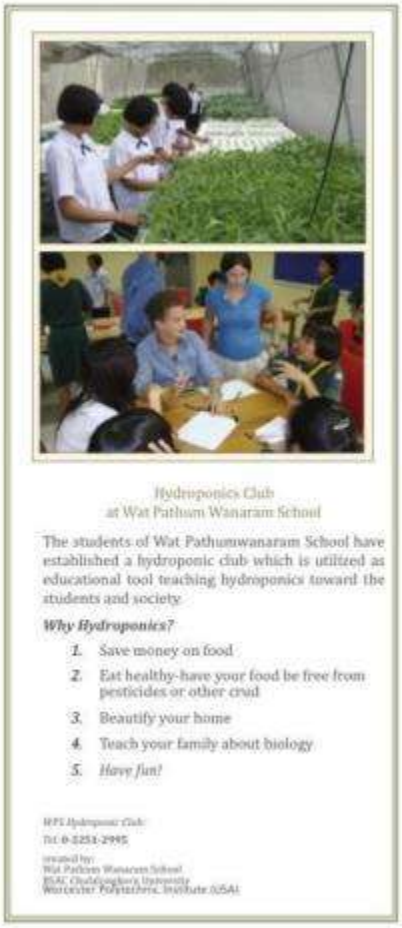
DRFT (Dynamic Root Floating Technique)

Deep Flow Technique(DFT)

Vertical Gardening

ความคิดสร้างสรรค์กับไฮโดรโปนิกส์

HYDROPONICS BROCHURE FRONT IN ENGLISH



Hydroponics Club
at Wat Pathum Wanaram School

The students of Wat Pathumwanaram School have established a hydroponic club which is utilized as educational tool teaching hydroponics toward the students and society.

Why Hydroponics?

1. Save money on food
2. Eat healthy-have your food be free from pesticides or other crud
3. Beautify your home
4. Teach your family about biology
5. *Have fun!*

WPS Hydroponic Club
Tel: 0-2251-2995

created by:
Wat Pathum Wanaram School
JGSEE, Chulalongkorn University
Worcester Polytechnic Institute (USA)

Wat Pathum Wanaram School

The primary and lower secondary school on the grounds of the Wat Pathumwanaram Temple has existed since before Thai education was nationalized in 1932. Nestled in a rice-growing area of Bangkok that later became the city's bustling financial district, WPS has persisted through hard times with a clever and resourceful administration, famously raising money by giving tours to foreigners. In 2007 H.R.H Maha Chakri Sirindhorn discovered the school on a walk through its neighborhood and, impressed, decided to take patronage over it (May, 2007). The school joins other projects in her effort to improve Thai primary education and skill development, particularly in science. As an urban school, it is an exception to the generally rural focus of her projects (H.R.H. Princess Maha Chakri Sirindhorn, 2007).

969/1 Rama I Road Pathumwan Bangkok

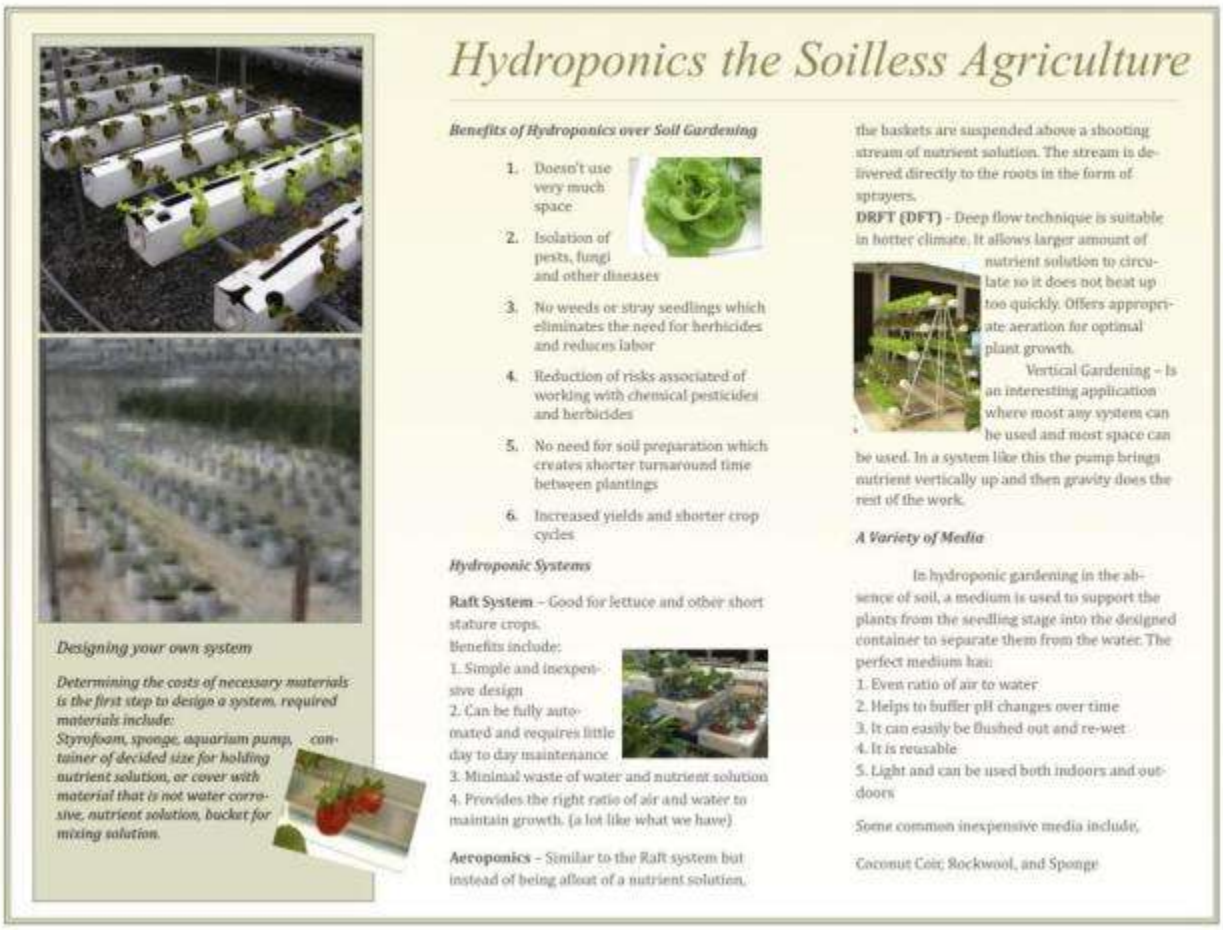
HYDROPONICS

WAT PATHUM WANARAM SCHOOL

What is Hydroponics?

Hydroponics is a means of planting and growing plants without the use of soil. In hydroponic gardening, the essential nutrients that would be provided to the plant from soil, is delivered to the plant in the form of nutrient solution.

HYDROPONICS BROCHURE BACK IN ENGLISH



Hydroponics the Soilless Agriculture

Benefits of Hydroponics over Soil Gardening

1. Doesn't use very much space
2. Isolation of pests, fungi and other diseases
3. No weeds or stray seedlings which eliminates the need for herbicides and reduces labor
4. Reduction of risks associated of working with chemical pesticides and herbicides
5. No need for soil preparation which creates shorter turnaround time between plantings
6. Increased yields and shorter crop cycles

Hydroponic Systems

Raft System – Good for lettuce and other short stature crops.
Benefits include:
1. Simple and inexpensive design
2. Can be fully automated and requires little day to day maintenance
3. Minimal waste of water and nutrient solution
4. Provides the right ratio of air and water to maintain growth. (a lot like what we have)

Aeroponics – Similar to the Raft system but instead of being afloat of a nutrient solution, the baskets are suspended above a shooting stream of nutrient solution. The stream is delivered directly to the roots in the form of sprayers.

DRFT (DFT) - Deep flow technique is suitable in hotter climate. It allows larger amount of nutrient solution to circulate so it does not heat up too quickly. Offers appropriate aeration for optimal plant growth.

Vertical Gardening – Is an interesting application where most any system can be used and most space can be used. In a system like this the pump brings nutrient vertically up and then gravity does the rest of the work.

A Variety of Media

In hydroponic gardening in the absence of soil, a medium is used to support the plants from the seedling stage into the designed container to separate them from the water. The perfect medium has:
1. Even ratio of air to water
2. Helps to buffer pH changes over time
3. It can easily be flushed out and re-wet
4. It is reusable
5. Light and can be used both indoors and outdoors

Some common inexpensive media include,

Coconut Coir, Rockwool, and Sponge

Designing your own system

Determining the costs of necessary materials is the first step to design a system. required materials include: Styrofoam, sponge, aquarium pump, container of decided size for holding nutrient solution, or cover with material that is not water corrosive, nutrient solution, bucket for mixing solution.

APPENDIX IX: TEAM CULTURE ASSIGNMENTS

NEAL ANDERSON

A Laid Back Lifestyle

I have enjoyed my two months in Thailand. Growing up in a rural area and living in a city the size of Bangkok is a big change for me. Luckily, Thai people are very friendly and they make living here pleasant. One of the most enjoyable, yet still frustrating aspects of the Thai culture is the laid back attitude. This manner is relaxing in day to day life because no one is in a rush to stay on schedule and people have a more pleasant mindset; however, this attitude can become frustrating when it carries over to the work place. This attitude I experienced for the first time a few weeks into the project.

My team had set up meetings with a teacher and the hydroponics club at our sponsor school on the same day. We had organized our work so that we could spend most of our time in the meetings. A few minutes before our meetings, we were informed that both were canceled because the students and teachers busy taking a standardized test. The school faculty knew that the test was going to be taking place before we requested meetings but did not inform us.

I was a little frustrated by this situation. We had planned our work around these meetings and they did not tell us that the testing was going to be happening. The teachers not telling us about the scheduling change made it seem as if they did not care about our meetings. Our Thai team mates were not bothered by discovering that our meetings were canceled. They saw the situation as normal and moved on with their work as if no change had been made. When I asked what they thought we should do about rescheduling the meetings, the merely shrugged their shoulders and said tomorrow would be fine. Matthew Willingham, an English teacher from the US working at our sponsor school, explained his aggravation with the situation later that day. Despite being a teacher, he was also not informed about the testing and that his classes for the testing days would be canceled. He saw it as disrespect since he was a teacher and they did not keep him up to date with changes to his classes.

I was frustrated with the situation because in my in experience in professional settings, canceling a meeting on short notice is not acceptable behavior. This is especially true if the

conflicting event was organized in advance. My Thai group mates explained to me that this type of situation was not abnormal for Thai culture. They expect scheduling changes and do not let the changes bother them. On the other hand, despite Matthew's six months of working in Thailand, he still has an American mindset about scheduling. When things changed without him knowing he became aggravated; which is unlike the Thai mentality. It was apparent that Mathew was having trouble accepting the Thai way and felt that the American way was better.

Looking back on the situation, I realize that the laid back, relaxed aspects of Thai culture can offer people of other cultures an eye opening experience in both a day to day experience and a professional setting. The mellow attitude makes the Thai people more relaxed and more pleasant to be around. In a professional setting the peaceful attitude makes people more understanding and less stressed when things do not go according to plan.

IVANA INDRUH

It Wasn't Just Another Tuk Tuk Ride

I get out of work and think to myself "Oh thank God for Fridays." For a moment, I forget that I am in the Central District of Bangkok, as I walk outside of the school and can smell the Fried Chicken at the schools co-op stand. I approach and Y to the two ladies who always smile at me and try to speak Thai to me even though they both know I cannot speak Thai. All the little kids are running outside kicking around a ball and playing badminton. The sound of laughter fills my ears and I catch myself smiling as I walk toward the Chicken stand. I pay my 10 Baht for two pieces of white chicken that I've been buying for a week now since I've discovered three kittens in the back of the school. I Y and say "Sawaat dii kha" and head to the back of the school. In a way, all of this reminds me of Croatia, the laughter of children, the friendliness of the people, and the baby kittens. I step through the door down the two stairs and I hear the little meows before I see the three little tails, like antennas in the air, running toward me. I crouch down, and try to take the breading off the chicken and tear the meat into smaller portions so they can chew it. Piece by piece I feed them individually so they don't fight over it. At this moment I'm at complete peace with where I am, I am completely comfortable and am enjoying the presence of Pumpkin, Peaches, and Jeff.

As I leave the back of the school and head out the front gate, heading toward Central World, it all starts coming back to me. "Oh yeah, you're in Bangkok" my mind says, as a whiff of sewage hits my nose and I have to fight to keep myself from gagging as I walk down the street toward the mall. I try to keep the thoughts from entering but the thought catches me, "I just can't wait for this project to be done and to just go home." As the thought enters my head, a wave of sadness overcomes me that I quickly brush it off and get back into the conversation with the group.

Instead of staying with the group to continue the hunt for just the book of "Teach Yourself Thai", I decide I am too tired and just want to go home. I consider walking but, after about the third time a tuk tuk driver asked me if I wanted a ride, I gave in. I was too hot, and my feet were starting to ache, so I figured what's 50 baht. This kind of thinking I suppose is exactly what they make their income of. It's the whites who're not used to the heat and more so to being drenched in sweat from walking just a mile in the heat, that the majority of the profit comes to

the Tuk Tuk driver. So after being asked "Tuk Tuk sir" I nod in approval and approach the driver. "Where you go?" Says the very soft-spoken voice of a man who could be my grandfather, hands covered in calluses with dirt under his fingernails, a t-shirt that has so many stains on it, it almost looks like they all belong on it. "Chula soi hok." I reply. It seems that no matter how much I try to say it right I just don't seem to put the right emphasis on it, because every time the driver repeats what I've said sounding more like "Julaaa soi hok!" I nod in approval and he motions me to sit. I've learned to negotiate the price before sitting in the Tuk Tuk. So I ask "Raakhaa thoow ray" and he replies "For you a good price, one hundred baht." I shake my head in disapproval and wave the driver off feeling a bit guilty I think to myself, "when could I ever get a ride for a little over three bucks to anywhere back in the states." As the thought finishes passing through my head I hear him yelling after me "OK OK how much you pay?" With definite frustration in his voice, as if he was thinking "This farang, what a cheap ass." Despite feeling bad, I can't help but feel a sense of victory in the question. "50 Baht" I reply and he motions me in. "Julaa soi hok!" He says one more time, and I nod in approval. I was so tired and out of it that I just sat there looking completely confused, and he'd shake his head in a jolly manner and just chuckle at the things he was saying to me, that I could not understand. At the sight of him chuckling, I couldn't really help myself, I'd chuckle right along. When we were stopped at a light, which seemed to last 3 minutes, he tried speaking Thai to me again, and when I replied "Chan paasaa Thai nit noi", he smiled even brighter than before and then tried to speak English to me. I thought it interesting that he would try to be so accommodating. "You go shopping?" He asked and I replied "No thank you." He'd flash another smile and then after collecting his words he said, "You go fish market?" I replied again with a "No thank you." Every time he offered me some place different to go and I replied with a no he just flashed a smile that I could not resist but smile back at. I arrived at Chula Soi Hok and got out of the Tuk Tuk, handed the driver 200 baht and went into the dorm, glancing back, I saw the man smiling so I Y'ed him and he Y'ed back, and we both went on with our day.

I'd like to think that everything happens for a reason, and that there was something greater than both the Tuk Tuk driver and me that brought us together that day. I believe that it's that greater something that opened my eyes and my heart that day as well. There was something in the way the man smiled when I said that I spoke very little Thai, and the way he tried to speak as much English to me as he could that made me appreciate the Thai nature and how

accommodating the Thai people are. In the American culture, the people I feel are less friendly and less accommodating than the Thai people are. If you manage to flag down a taxi, not only will you be overcharged but at no point will the driver suggest you get out because there is traffic and you are only losing money.

In Thai culture, people of all trades are more accommodating in general. People are brought up knowing that in order to be given respect you must give it. The only folly with that is that not everyone gives back the respect the same way the Thai people do, in which case the Tuk Tuk drivers and the Taxi drivers are taken advantage of. Given the size of the city and the high temperatures and many tourists, it's no wonder there are so many Tuk Tuk drivers and Taxi drivers around. It is an opportunity of income for the driver. In some cases, it may be the only income that the family receives.

When I think back to Mr. Tee, my Tuk Tuk driver in Cambodia, I think of an honest man doing an honest job just trying to survive and put food on his family's table. I think of a father that has to be away from his family for months at a time because he works every day, and can't make the commute to the countryside on a regular basis, as it is a loss of income. I think of a hard working dad who is trying to provide the money necessary to put his two daughters through elementary school. Maybe it was this thought that got me to give this Tuk Tuk driver what I would consider a small gesture of kindness.

Don't get me wrong, I know that there are those drivers out there that are trying to take advantage of the "white" people. However, when you really stop and think about it, even a 200-baht ride from Central World to Chula Soi Hok in traffic is not an expensive ride comparing to the same conditions back at home. So maybe they take advantage of our lack of knowledge of the area, but again there is a reason for them charging us as much as they do. We don't notice the difference in our pocket, we still feel that we are getting a "deal" and at the same time they are making an income for themselves and their families.

I can't say that I don't get upset or frustrated when a taxi or a Tuk Tuk tries to charge me four times what I know it should cost to get from point A to point B. It's human nature to get upset about things like that, just as the Tuk Tuk driver got frustrated with me when I reduced the price to 50 Baht. In reality we had the same thought cross our mind, the question of "WHY?" Why is he over charging me when I know how much it should cost? and Why is this farang refusing to pay me the one-dollar extra what is a dollar to her? I can sit here and claim that if I

were in the driver's shoes I would be fair and charge the right prices, but again I would be lying. I cannot pretend I know what situation the driver comes from, I cannot pretend I know all the reasons why he is charging me 100 Baht instead of the 50 it would cost, but I can say that if I was in his shoes I would most likely do the same thing. I would have the idea of well what is another dollar to you Mr. Three Piece Suit. I would do all I need to do to put food on my family's table, to pay the bills, to put my children through school; I can't even claim that if I was in his shoes I would be as accommodating to the passenger, because I feel that in my culture expressing emotions is commonplace, so I would do just that, give them my piece of mind.

Although I gave away 200 Baht that day, I received an amazed and warm-hearted smile from a complete stranger, a smile I will never forget.

ZAKKAI KAUFFMAN-ROGOFF

Trying to Help

During my first weekend in Bangkok, I went to on an evening trip to Banglamphoo with four other WPI students. After exploring various landmarks and eating near Wat Suthat, we strolled down a street looking for dessert. We stopped at a small bakery that was open to the sidewalk, manned by a single woman behind a large glass case of sweets. As I paid for my slice of cake, I saw something move behind the glass. One of the trays was covered with ants. Our group started looking and talking, some of us expressing disgust and others concern. The proprietor, who appeared not to speak any English, was confused, and then quickly became concerned as she read our faces. Our group exchanged words and decided to let the woman know about the problem --we reasoned that she should have a chance to deal with the ant problem before any other customers were put off by it. We tried pointing at the food, but she thought we wanted to buy it, so we gave up and started gesturing with a beckoning motion and doing our best to tell her, in Thai, to come to our side of the case, saying *"maa,, maa."* The shopkeeper continued to look confused, even after we thought we had made our message clear. As we continued to beckon, she turned her gaze to the ground and began to shake her head quickly every few seconds. She looked nervous and somewhat dejected. We eventually gave up and walked away, thinking that it was a lost cause and that we were making her very embarrassed. We strolled by in the other direction later and saw that she had cleaned out the tray, salvaging what little food was clean and replacing it, free of ants, in the case.

The group feared we had hurt the shopkeeper's feelings, when all we had intended to do was help. In the cab ride on the way home, we came up with a few interpretations of the situation: we had heard that Thais were more concerned with "saving face," or maintaining social dignity and decorum. This seemed to explain the shopkeeper's extreme embarrassment during the encounter. However, this theory did not convincingly explain her unwillingness to come look at the problem. Instead of expressing her concern for her business and customers by being attentive to our warning, she stayed put and seemed to retract. Perhaps, we hypothesized, she thought we meant to scam or take advantage of her or were trying to mock her; it is possible that the reason she refused to leave her counter was not out of embarrassment but out of suspicion that taking our advice would somehow come to a sticky

end. There are many scam artists in Thailand, but it seemed unlikely to me that a group of young foreigners would prey on a local shopkeeper; the scam usually goes the other way in my experience. However, it is not unlikely that she thought we were somehow mocking her and did not want to play along. I was very afraid that this was the case.

My primary feelings during the encounter I described were anxiety and annoyance – anxiety because I feared I was upsetting the shopkeeper and that she would perceive me as an inconsiderate *faràng* tourist. I also felt social embarrassment because of the awkward interaction. I further worried that throughout the night the ants would lead to poor sales that would be inexplicable to the shopkeeper-especially if other Thais were unwilling to point out the insects. I felt annoyance because my interlocutor was not doing as I asked or acknowledging the issue I was attempting to bring up. I was also annoyed with my inability to express my thoughts in Thai in a polite and gentle way. I feel that had I shared a language with the woman the encounter would have been considerably less awkward for both of us.

I would hypothesize that a Thai person with a personality similar to mine (outgoing, talkative, empathic), would have done the same thing in my situation. However, they probably would have felt more awkward doing so than I would have while doing something similar in my home country. This Thai version of me would have strongly desired to avoid embarrassment, but would have gone through with the action anyway. I believe this because in my experience Thai people are quite concerned for others and most would take this opportunity to help a stranger in need.

I learned from this encounter that when in Thailand I need to handle embarrassing or awkward situations with extreme care. Thai culture is more concerned with saving face and I am not familiar with its nuances. I have been trying to put this in to practice in recent months, and I wonder if my style of confrontation has changed enough that I will notice a difference in my behavior when I return to the USA. I would not be surprised to find my style of interaction not confrontational enough for dealing with other Americans.

BRIANNA LEDWITH

TAXI-METER

Since arriving in Thailand I have experienced many different aspects of Thai culture. While most of my cultural immersion has been a positive experience, some events have been negative and can be prevented if students are warned ahead of time. Thus I will strive to warn future project students about one of the main problems I have faced while in Thailand: Taxi Drivers. Many taxi drivers are honest working people, however some of them hope to make some extra money by overcharging tourists. Unfortunately almost all Caucasian people are instantly considered to be tourists, and this is where problems can arise between drivers and their foreign passengers.

There were many instances when taxi drivers have tried to charge me a flat rate for a taxi ride, but I will only document two distinct instances here. The first occurred on the second night the WPI students had arrived in Thailand. A group of WPI students wanted to go out to dinner and decided to take a taxi to get there. The taxi driver offered to take the group for 200 Baht. Since our group was new to Bangkok and was unfamiliar with taxi prices, we accepted the driver's offer without question and were taken where we wanted to go. We found out later that the taxi ride should have cost under 100 baht.

After I lived here for about a week, I became familiar with the taxi system and learned that a flat rate will always cost more than the taxi-meter will cost. My IQP team had to take a taxi to class most days and thus we knew that a taxi ride to work should cost between 50 and 75 baht depending on traffic. The first two weeks of getting taxis were very uneventful, the taxi drivers were friendly and accommodating and there wasn't question of driving us without the meter. However, one particular busy morning, this was not the case. It took our team three full attempts to get a taxi to give us a fair price. And even then it was still a flat rate rather than the meter which would have been cheaper.

At the time that these two instances happened I interpreted them differently based off of my experience in Bangkok. The first time I was offered a flat rate for a taxi, I thought the man was giving us a good deal because there were so many of us and we wanted to go relatively far away. I was pleased that he had been kind enough to do us the favor of charging us a flat rate.

However, now I have learned that it doesn't matter how many passengers there are, the fee is always based on distance. So for our group we should have only needed to pay about 100 Baht to get to our destination. The second instance I documented happened after I had been in Bangkok for a few weeks and was familiar with the taxi system and what was considered giving a fair price. When the drivers tried to make us pay double what we should pay I interpreted the situation as a negative one. I knew I was being told a higher price because I was a foreigner, it didn't matter whether or not I was a tourist. I was told before coming to Bangkok that there is "the Thai person price" and the "foreigners price" but I had no idea that it would extend even to meter-taxis which were put in place to make sure everyone is charged the same.

The first time a taxi driver ripped us off, I didn't realize it was happening. I felt happy that the Thai people were being so accommodating that they were giving us a special deal for a taxi ride. In hindsight I blame myself for not knowing better and accepting the "deal" so readily. However, when taxi drivers continued to attempt to rip me off even after I made it clear that I knew the price was too high, I became angry at the taxi drivers. I realized I was being targeted for being a foreigner. I realized that they assumed I had lots of money and wouldn't mind spending more even though I made it clear I wanted to be charged a fair price. I was angry that people assumed I was a "rich white person" without taking the time to even try and find out. When I was younger I used to think that stereotypes weren't that prevalent in everyday life, but was upset to find out that while in Bangkok, they are. I am hoping that by warning others about these assumptions, this stereotype of foreign visitors can start to be eliminated from the Thai merchants and taxi drivers.

I believe the taxi drivers had a different interpretation of the situation than I did. The first taxi driver most likely felt the situation was a positive one, because he got more money while we didn't even realize we were being ripped off in the first place. That way everyone was happy by the end of the trip. The driver decided if someone was naïve enough to agree so readily to a set price then it was their own fault for not knowing better. The second set of taxi drivers who offered to take my team to work for more than we usually paid knew they were charging too much, and our team made it clear we also knew. However, they were probably confused as to why we wouldn't agree to pay extra for the ride. Our Thai language teacher warned us that most Thais assume that all Caucasian people are rich and that they come to Thailand because they

have extra money to spend. The taxi drivers probably didn't understand that this is a stereotype and assumed that our group was being too cheap by not taking their "kind" offer. Since the drivers assumed that we had lots of extra money it didn't make sense to them that we wouldn't just give them a little extra for driving us. While I was angry that the taxi drivers were overcharging me, they were probably angry at me for not just paying the fee they offered. As they assumed I had lots of money, they would have been angry when I told them I was unwilling to pay extra. Why wouldn't I just give them some of the extra money I had just lying around? Why wouldn't I share the wealth? Unfortunately, these assumptions made a neutral situation into a negative one. The drivers want to make as much money during the day as they can and overcharging "rich" people is one of the many ways to do it. They probably felt that they were doing something perfectly acceptable and that the situation only became negative with our refusal to pay. The hard part of this situation is that the taxi driver was partly right. Who determined the "meter-rate" is fair? There is no way for the taxi drivers to complain at how much the going rate for a taxi ride is, as it is very un-Thai to complain when one is unhappy with something. They also don't want to rip of other Thai people, who could be in the same situation they are in, and who would be offended by the dishonesty of the driver. The taxi drivers most likely see tourists as foreigners who don't know the Thai way, and who are almost expecting to get ripped off. The taxi driver can't afford to go to another country so his assumption that tourists have more money is true, though assuming we are "rich" is a stretch.

When we got to work the morning it took three attempts to find a taxi, our team shared our experience with our Thai group members. They were both shocked that we encountered not one, but three taxis that refused to let us use the meter. They were also appalled that this should happen since they know that we are college students who don't have lots of extra spending money on hand. They interpreted this situation very differently than the taxi drivers, they knew that the price was unfair and that we shouldn't be charged that much. However, our group members have different insight than the taxi drivers do. They are relatively westernized and have learned that some of the stereotypes about foreigners aren't true, including the stereotype that all foreigners have money. The Thai students were embarrassed and upset that this had happened to our team. However, they know our background and are our friends, rather than someone trying to make money from us. They felt that it was unfair that we should have to deal with this situation when they were treated fairly. They realized that we were being targeted because of our race and

felt that it was unfortunate that it was something we couldn't control. They were also offended that the taxi drivers were acting contrary to the traditional Thai culture of being accommodating and kind. Most Thai people believe strongly in karma and the idea that "what goes around comes around" and thus act fairly toward everyone so that later in life others will act fairly towards them. Thus our group mates were shocked that so many people had tried to charge us unfairly.

I am hoping that by passing along this information to the future teams, we can help prevent these situations from happening. If we can start by eliminating the assumption that it is alright to rip off foreigners because they don't even realize it's happening, we can then work on eliminating the stereotype that we all have a lot of money.

APPENDIX X: GARDEN HANDBOOK

WPI/CHULALONGKORN UNIVERSITY IQP-SSP TEAM

Garden Handbook

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PURPOSE OF THE TRIAL

The team believes that the changes implemented in the trial area will produce a higher yield and will likely lead to more nutritious and better-tasting vegetables. The team has also sought the opinions of experts and examined scientific literature to verify that the changes will have a positive effect. The team would prefer to undertake a series of controlled experiments to determine the unique effects of each proposed change, but time, space and money limitations make this impossible. Instead, the team will rely on experts and literature to guarantee as well as possible the utility of the changes.

The goal of the trial will be to demonstrate that the proposed changes will not have a catastrophic effect on the garden. If the trial area fares better than the rest of the garden, the school will know that the team's proposed changes are worthwhile. If no change is observed, the school will know that the changes are very unlikely to cause failure in the garden. In this case the team will still recommend that the changes be implemented; the opinion of the experts consulted is that the changes will, on average, improve the garden in the long term. If the trial area fails catastrophically, the team will have to discard its proposed changes and leave improvement of the garden to a 2011 IQP team.

NOTE

This manual was created to assist the staff of WPS in implementing the changes that the team made during the course of the trial. The manual includes a detailed explanation of the changes the team implemented and the reasons for implementing chosen changes. It also includes the results determined from the trial. A section of the manual focuses on the various materials that would be required for implementing the chosen changes such as the necessary materials including resources, approximate man hours, as well as the money necessary to implement the necessary changes. The final section of the manual is dedicated to describing detailed step by step methods of implementing the decided changes.

Due to time limitations, in this trial the team ONLY performed the trial on morning glory plants. The team lays no claim that implementing suggestions on following the same procedure for other various plants that can be grown hydroponically will produce the same results. This handbook and its results are related directly to morning glory plants.

LIST OF MAINTAINABLE VARIABLES

Observation is essential. Noting any changes that occur to the garden on a day to day basis is important although being very familiar with the garden one may overlook certain aspects that a foreign eye may catch. It would be beneficial to have someone who is familiar with hydroponics, to be invited to the garden and to note any adjustments that they see that may need to be made. This person should either be an expert or someone who is familiar with the field of Hydroponics.

VARIABLES TO NOTE

NUTRIENT SOLUTION LEVELS WITHIN THE BUCKETS

The nutrient solution within the bucket should not be filled to the brim of the bucket. This should be done to avoid waste of nutrient solution and can help in maintaining appropriate pH and EC values.

NUTRIENT SOLUTION LEVELS WITHIN THE PLANT CONTAINER

The nutrient solution should not be too high as then the roots do not get the proper aeration that is needed; however, at the same time the water levels should not be too low either as then the water temperature will rise which can be just as costly to the health of the plants. Ideally this water level should be kept at approximately 2 to 2.5 inches deep. This way the plant receives the oxygen it needs and its roots remain at a reasonable temperature.

NUTRIENT SOLUTION AERATION

When checking the systems it is important to note if any of the holes which deliver water from the nutrient tank to the plant tank are clogged. If any of them are not expelling water with the correct pressure they should be cleaned out. One will note if they are working properly as when the stream of water being expelled form it comes in contact with the water in the plant tank bubbles will form. Improperly working systems will either not expel any water, or will simply trickle.

Another concept is to insert an aeration rock into the nutrient tank. In this way the rock creates aeration to the nutrient solution before it is even delivered to the plants. Some aeration will be lost in the process so ideally both parts would work together to create the best possible results.

EC LEVELS SHOULD BE MONITORED

EC levels should be monitored closely. These levels determine the amount of nutrients that the plants are receiving. The higher the EC the more nutrients the plants are getting; however, more nutrients is not necessarily good for the plants as it can cause over saturation and it can kill the plants just as under saturation might. When the solution is mixed, the EC should be stable before introducing the solution to the plants. Below is a table of suggested EC values for the plants currently being grown in the garden. This data is from both experts and current growers in Thailand. In Table 1 below, one can see that there are two different values of EC for each plant. The EC Stage 1 value is the EC level that the plant needs when it is transplanted from the seedling stage into the nutrient bed as well as when the nutrient solution needs to be changed to EC Stage 2. As the plant matures the saturation of nutrients it requires changes. These changes in value affect the efficiency of the plant growth. Although the team can not speculate if the changing of nutrient solution had a drastic positive effect on the plants, the team can state that it did not have any negative effects and that the overall results were better for the morning glory trial.

Plant Being Grown	**EC Values Between**
Cabbage	2.4-2.8
Lettuce	1.0-1.5
Morning Glory	1.5-1.9
Tomato	
Spinach	1.8-2.0
Kale	4.0-4.5

TABLE IV: PROPER EC LEVELS FOR VARIOUS PLANTS OVER TWO STAGES

PH LEVELS SHOULD BE MONITORED

Just as EC is important in monitoring the nutrient saturation, the pH notes the amounts of acidity or alkalinity in the nutrient solution. If the pH is at 7 it is neutral, above 7 is basic, and below 7 it is considered to be acidic. Any unit change in pH can highly affect the ion availability to plants. Between the pH of 6.0 and 7.0 most favorable nutrient uptake occurs. If the pH should be raised to between 6.5 and 8.0, elements such as iron, manganese, and zinc become less available. At the same time if the pH is lowered below 6.0 molybdenum and phosphorous availability decreases. The bicarbonate iron may be present in large enough quantities to interfere with normal uptake of ions and can be detrimental to optimum growth, if pH levels are very high (Resh, 1995).

PESTS SHOULD BE CONTROLLED

Even though one does not have to worry about herbicides in Hydroponic gardening, one still needs to consider a way of keeping all pests out of the garden. Most often the best way to do this is to have the garden in some sort of enclosure. The garden at WPS has netting around it to keep pests out. This is a good start, although the team may suggest a few ideas to improve upon the efficiency of the netting.

In Figure 1, one can see that although the netting is there, there are various entry points for rodents and other small animals, allowing them access to feast on the plants in the garden. A way to fix this would be to utilize 2x4 material or other such material and pull the netting around the 2x4 and then securing the 2x4 to the roof via screws. This would keep the netting taut and prevent gaps or openings in the netting for small rodents to enter. Also the door has a fairly large gap that a small bird or mouse or any other small insect could enter through to the garden. The team suggests an overlap in the flap in the door, so that when the door is closed there is no gap to allow this access point.

FIGURE 14: ACCESS POINTS IN THE DOOR (LEFT) AND NETTING (RIGHT)

In addition, the team put together a water based solution that could help keep pests off the vegetables. The solution was created by using the ideas of various online sources and trying to combine them. The solution consists of ingredients such as mint, onion, garlic, tobacco, and soap. The one thing to keep in mind is that after the plants are misted to be kept cool, the solution needs to be reapplied. In the future perhaps the reapplication of the solution could be automated by introducing the solution directly to the water as it is being sprayed to cool the plants.

NUTRIENT SOLUTION BUCKETS SHOULD BE COVERED WITH STYROFOAM

All the nutrient solution should not be open to visible light. Because of the large number of nutrients, if the solution is exposed to visible light, algae will grow rapidly and absorb many of the nutrients that the plants need to reach optimum growth. Simple precautions could take place. When mixing the nutrient solution, do so in an opaque container and cover that container while waiting for the EC and pH levels to stabilize, mix the solution out of the direct sunlight.

Before the solution is introduced to the plants, the nutrient storage tank as well as any part of the system that will be getting in contact with the solution should be cleaned off. Cleaning can be as simple as rinsing it off with boiling water, scrubbing any leftover sediment from the previous batch, and then rinsing again with boiling water. Cleaning every few months with a

bleach solution could also be beneficial in maintaining the health of the system as a whole.

The cleaning of the system between transplanting ensures that any sediment that was left by the previous batch is removed as well as any dried up solution that may be present and not visible. Both of these can cause alterations in both the EC and pH and can have an effect on the growth of the plants.

When the solution is introduced to the system, it is essential that none of the solution is exposed to visible light. Placing the containers in the shade will decrease how quickly the algae grow, but once algae is present the solution needs to be removed and the system cleaned entirely as the algae will spread to where there is most nutrients. Algae are dangerous as it can cause technical issues as well. The algae can cause malfunctions with the pumps and clog systems to prevent full functionality; therefore taking small steps in preventing algae growth can lead to less problems and less work, as well as less losses in both plants and materials, in the long run.

THE TEAM'S APPROACH TO IMPROVING THE GARDEN

GIVEN INFORMATION

Upon receiving the project description, the team was aware that a portion of the project would have to be dedicated to determining how to improve on the efficiency and yield of the current garden at WPS. The team was not informed of what type of system was being used, or any other variables, but rather the team worked from scratch in familiarizing themselves with hydroponics including the various systems, nutrient solution formulation, electric conductivity (EC) and pH and the reasons why they play an important role, plant life and plant health, hydroponic hygiene, potential problems and the how –to of fixing those problems.

RESEARCH

The team researched all relevant topics to hydroponics. This was done by searching the various databases, exploring the literature including *Hydroponic Food Production* by Dr. Howard M. Resh, seeking advice of hydroponic experts in both the United States and Thailand, visiting farms in Thailand to get a feel of how the farmers run their farms and what approaches works for them, as well as exploring the online sources in determining possible solutions to some problems not necessarily directly related to Hydroponics, such as pest control. After completing over 7 weeks of research and continuing research as field work progressed, the team was able to analyze to the best of their abilities the potential problems as well as the ways of fixing those problems.

ANALYZE POTENTIAL PROBLEMS

Before the WPI team's arrival in Bangkok, problem analysis was dependant on information given to the team by the school as well as some of the problems witnessed by the Chula team members in their visit to the school. The problems witnessed included poor plant health, as they were eaten by bugs and rodents. The cleanliness of the system was an issue. Also the large amounts of waste in both plants and nutrient solution occurred. A more in depth

analysis of the garden occurred upon WPI's arrival to Thailand. Here the entire team of 6 took to analyzing the state and condition of the garden.

ANALYZE THE STATE OF THE GARDEN

The analysis of the garden was done to determine what aspects of the already functioning garden could be altered to create an even better more efficient garden. The team noted the high EC values between the various tanks; also there was an extensive growth of algae in the nutrient solution buckets as well as in the nutrient solution beds. In Figure 2 one can note the comparison between two solution beds. The one on the left is filled with algae and the one on the right is kept clean.

FIGURE 15: NUTRIENT BED COMPARISON PHOTO (LEFT COMPARISON GROUP NUTRIENT BED, RIGHT TRIAL GROUP NUTRIENT BED)

The garden was functioning well enough, but its functionality could be largely increased if a few steps toward improvements would be taken. The determined problems were based simply on observations made by the team.

DETERMINE ACTUAL PROBLEMS

The problems that the team chose to address included the following:

1. Cleanliness of the garden

2. Altering the nutrient solution to include more nutrient parts
3. Monitoring the EC of the nutrient solution
4. Monitoring the pH of the nutrient solution
5. Spraying a water based solutions to keep pests clear of the plants

DETERMINE POTENTIAL SOLUTIONS

Here are the approaches the team took to solving the individual issues in their morning glory trial. Once again the team cannot claim that any individual aspect is responsible for the positive results of the trial, but the team can lay a claim that if all aspects are changed for the other plants, than there will not be any catastrophic results, as long as the appropriate conditions are met.

1. CLEANLINESS OF THE GARDEN

The team took out the plastic nutrient bath containers as well as all the pipes and hoses that connect the entire system together and laid them out on the roof. First the entire system was rinsed with hot boiled water. Then the team of four students took sponges and scrubbed off the residue that was left by the former plants. The team rinsed the system with a hose and then once it was entirely cleaned, the team once again washed it with boiling water before it was replaced to its original position.

2. ALTERING THE NUTRIENT SOLUTION TO INCLUDE MORE PARTS

The team was given a formulation for morning glory from Khun Prasert. This formulation was in two parts, Stock A and Stock B. In Tables 2 and 3 below, the parts and measurements of each stock are given respectively. This formulation was used by Khun Prasert at his own farm. The formulation is 2 years old and suggests an EC of 2.4 - 3.6 and a pH of 5.2-6.5.

Stock A (mixed into 10 L of Water)	
Compound	**Amount needed (g)**
Calcium nitrate	1000

Iron Rasolin APN	60

TABLE V: STOCK A FORMULATION OBTAINED FROM KHUN PRASERT

Stock B (Mixed into 10 L of Water)	
Compound	**Amount needed (g)**
Potassium nitrate	700
Magnesium sulfate	500
Mono potassium phosphate	150
Mono ammonium phosphate	50
Nick-spray	15
Manganese –EBTA	10

TABLE VI: STOCK B FORMULATION OBTAINED FROM KHUN PRASERT

When mixing the solution for the trial, the team could not get certain parts unless they were bought in bulk. So the formulation the team followed can be seen in Tables 5 and 6 below. Although it does not include all the parts as the table above, it includes more parts on nutrients than the nutrient solution that is being used does. The team maintained the EC to be between 1.5-1.9 and pH was maintained between 6.0 and 7.0 for the most part.

Stock A (Mixed into 10L of Water)	
Compound	***Amount (g)***
Calcium Nitrate (15-0-0)	1000
Iron EDDHA 6%	60

TABLE VII: STOCK A FORMULATION BY TEAM

Stock B (Mixed into 10L of Water)	
Compound	***Amount (g)***
Potassium Nitrate	700
Magnesium Sulfate	500
Mono Potassium Phosphate	150
Mono Ammonium Phosphate	100
Nick-Spray	50

Manganese-EDTA	15

TABLE VIII: STOCK B FORMULATION BY TEAM

Although the team's formulation does not include as many of the parts, overall the results show that the team's plants grew healthier and faster than the control group. As most of the team's plants were harvested and sold within 15 to 18 days rather than the expected 25 day cycle.

3. MONITORING THE EC OF THE NUTRIENT SOLUTION

From the very beginning, the team began monitoring the EC of the morning glory of the plants. The measurements were taken every day with the exceptions of weekends. The values of the EC went from 1.9 from when the plants were first harvested to 1.5 the 15th day of harvest. For the final 10 days the team planned to make a new solution for the plants with an EC level to be on the higher end of the spectrum, but the majority of the plants were harvested that weekend.

The EC is simple to maintain. When mixing the solution, mixing part A first and completely dissolving it in water, and then mixing part B and completely dissolving it, then combining the necessary parts of A and B together and allowing the solution to sit for about an hour is essential. By allowing the solution to sit, within an hour the EC will stabilize and once it does, the EC can be properly measured. If the EC is too high more water can be added to the solution to lower the EC, if it is too low, there is too much water in the solution and more parts of the nutrients need to be mixed in. It is better to mix a higher EC solution and to add water than vice versa.

The team did not alter the EC levels at all, but only monitored them to make sure that they remain within the desired ranges. For the first week, the EC values read to be 1.9 then gradually they began to decrease down to 1.5. If this was to happen earlier, then more nutrient solution would have to be added, or an entirely new solution created to ensure proper growth. Even though majority of the plants were harvested sometime within the 15 -17 days a new solution was created to prevent malnutrition and promote faster and better growth to the rest of the plants.

4. MONITORING THE PH OF THE NUTRIENT SOLUTION

The pH levels were monitored to see that maximum amounts of nutrients would be absorbed by the plants. These levels too were fairly stable throughout the process. The only significant jump that was noticed was when the level jumped to 7.45, but the team

believes that this was because water was added to the solution, thus raising the alkalinity of the nutrient solution.

The team suggests that if the plants require more fluids, that another solution with the desired EC and pH levels be created first and then that solution to be introduced to the plants rather than just adding water to the solution. By just adding water both the pH and the EC can be affected and although the plants now have access to more fluids, they are not receiving the proper amounts of nutrients. As noted above, the pH should be maintained between the levels of 6.0 and 7.0 to ensure maximum uptake of nutrients.

The team's measured values of the pH were on the high end of the spectrum, measured closer to 7 than 6, but they were still maintained between the two values. The team did not have to make any adjustments to the morning glory plants as far as the pH was concerned, monitoring of the pH showed us that. The pH was also monitored on a daily basis. This may not be the case for all plants. If the case should be that the solution requires being more acidic an acid such as phosphoric acid can be added in very small parts slowly to the solution. The acid should be added in measurements of milliliters over ten minutes and then re-measured. This will ensure that the nutrient solution is not becoming more acidic than necessary. The procedure is the same if the solution requires being more basic, a base such as potassium hydroxide can be added following the same procedure as adding more acid. Balancing the pH can be very time consuming and can result in creating a very imbalanced solution, where the pH keeps fluctuating to extreme amounts. If this should be the case, it may be more beneficial to completely change the nutrient solution. This requires personal judgment.

5. SPRAYING WATER-BASED SOLUTIONS TO KEEP THE PLANTS CLEAR OF PESTS

The formulation for the solution can be found on page ten in Figure 2. This formulation is not intended to kill any pests but rather keep them from feasting on the plants being grown. The formulation was created combining information from various online sources.

The plants should be sprayed with this every day both in the morning and after they were misted by the sprinklers. This is a key point. When the sprinklers are turned on to cool the plants, they also wash off the solution and expose the plants to the pests again. In order to prevent this, the solution should be used at least twice a day.

As mentioned above, if it is too much work to have someone spray the solution on the entire garden, perhaps an automated system could be used to introduce the appropriate amount of solution to the sprayers, so that when the plants are being misted to cool off they would also be misted to keep the pests clear.

HOW DO THESE CHANGES IMPROVE THE GARDEN?

As observed throughout the trial. The following four topics can describe the overall improvements to the garden, by introducing the changes mentioned in the above sections.

GREATER YIELDS

In Figure 3 the morning glory is much denser and much greener than the control group. The plants on the right look healthier and fuller than the plants on the left, whose leaves look more yellow-green in color and are less of the healthy green color.

FIGURE 16: COMPARISON PHOTO OF TRIAL RUN ON MORNING GLORY PLANTS (LEFT IS THE COMPARISON GROUP, RIGHT IS THE TRIAL GROUP)

From observation the plants look healthier and are much bigger during the same stages of life. For an example refer to Figure 4 where we have two plants side by side comparison at 12th days of growth. The plant on the left is the plant from the trial and the plant on the right is from the control group.

FIGURE 17: SIDE BY SIDE COMPARISON OF PLANT HEIGHT AT 12 DAYS OF GROWTH

FASTER TURNAROUND

At the beginning of the trial, the team anticipated the turnaround rate between the planting and harvesting to be a total of 25 days as suggested by the farmers and the school. However, the team discovered that approximately half of the plants were harvested the weekend of February 12, 2010. This puts the turnaround time to be somewhere between 16-18 days. By doing a few calculations we find that in an 18 day cycle there is a possibility of running maximum of 20 cycles per year which would result in a total of 4000 plants if only 200 were to be grown per cycle. In a 25 day cycle there is a possibility of running a maximum of 14 cycles per year and resulting in a total of 2800 plants if only 200 were to be grown. This means that on average the 18 day cycle growing 200 plants per cycle produces 1.429 times more produce annually. In terms of money if each plant were to be sold for 1 Baht, annually the result would lead to a 1.429 times more income. This may seem insignificant in the terms of 200 plants being grown, but if you double the amount of plants being grown form only 200 to 400 per cycle, the potential income also increases by a factor of 2.

OVERALL PLANT HEALTH

The plants in the trial look healthier and much denser than the control group does. The fuller plants would be also more appealing to the consumer rather than the smaller less appealing plants might. Also the healthier the plant is when introduced to the consumer, the greater the benefits for the consumer. If the consumer is eating the plant or creating a dish with the plant that looks better, not only are they providing better food to the customer, but they are promoting better health as well.

RESOURCES AND MATERIALS NEEDED AS WELL AS ASSOCIATED COSTS

EXPERTS

PRATHOMCHAI HYDRO TECH CO., LTD
MR. SONGYOS YONGSIRI

111/1 Moo 2 Sothorn Chachoengsao 24000

Tel: 0-3851-4160

kamnuntun@soillesstun.com

www.soillessyun.com

Hydroponic provider in Thailand. Has 20 + years of experience in the field of hydroponics. He both builds and installs the DRFT system. He has much knowledge about potential problems as well as solutions to the said problems.

He is an expert in hydroponics in Thailand and is familiar with both the growing conditions as well as the climate and pest conditions between the seasons. He seemed very interested in helping the team improve the current state of the garden.

ERIK BIKSA (ADVANCED NUTRIENTS EXPERT)
ERIK@ADVANCEDNUTRIENTS.COM

Erik is an expert in the field of Hydroponics. He can assist in answering in nearly any question pertaining to Hydroponics, from the way to set up systems to the appropriate anti pest precautions to take.

Expressed interest in providing nutrients for the teams trial maybe he'd be willing to provide nutrients to the school.

WESCO CHEMICAL (THAILAND) CO., LTD.

9/40 Moo 7 Soi Latphrao 71 Latphrao Road Latphrao

Bangkok, Thailand 10230

Contact : 662-5399003 662-9324993

Fax : 662-5387603

Wesco Chemical (Thailand) has supplied the nutrient chemical and provided useful advices throughout the project.

OTHER FARMERS

Khun Prasert owner of 304 Hydroponic Farm
Khun Samran owner of Samran Hydroponic Farm

Collectively have grown vegetables for 1.5 years, using the DRFT system as provided to them by Khun Thun. They have much knowledge of how to set-up a hydroponic farm as well as how to run a farm efficiently and with little manpower.

MATERIALS

MORE PARTS FOR THE NUTRIENT SOLUTION

More parts can be purchased from Wesco Chemical. These parts are less inexpensive when bought in larger quantities.

TOBACCO

Tobacco can be purchased from nearly any store or stand. A single bag of tobacco can be used to create enough solution to last a few weeks. The price of this tends to be between (Approximately 30-50 Baht per bag)

GARLIC

Garlic can be purchased from nearly any supermarket for a relatively inexpensive price of (Approximately 30-40 Baht per clove)

ONION

Onion can be purchased from nearly any supermarket for a relatively inexpensive price of (approximately 20 Baht per onion)

MINT

Mint can be purchased from nearly any supermarket for a relatively inexpensive price of (approx. 25 Baht per bunch)

ASSOCIATED COSTS

Man power required to implement changes such as cleaning the system requires only a few hours between cycles. Implementing changes such as covering the nutrient buckets with Styrofoam is a one time required work, and the covers can be re-used thereafter. More parts to the solution is done same as previously, only adding more ingredients to the mixture, this will not take up any more time than usually, especially if materials are at hand.

Associated costs may seem like a significant amount, as the nutrient parts may be fairly expensive at first, but in the long term these costs will most likely be covered by the amount of produce that is not lost, as well as the quality of the produce that is sold.

DISCLAIMER

These effects of the changes noted in this manual will vary between the seasons. The species of insect and other pests may vary depending on the season, and the solution created may or may not have the same effects. The temperatures between the seasons may result in higher nutrient solution temperatures which may have negative results. Also the trial was only tested on morning glory, due to time restrictions and the team cannot guarantee that the same results will be seen for other various plants. The team is relying on the advice of experts and literature to guarantee as well as possible the utility of the proposed changes. The goal was to demonstrate that none of the changes resulted in catastrophic failures in the garden. The changes recommend that the school implement into the rest of the garden did not produce any such result. Instead of empirically verifying the utility of all the proposed changes, due to time restrictions, the team will rely on scientific literature and the opinions of experts to verify the long-term utility of the noted changes.