SCIENCE LAB ACTIVITIES FOR SECONDARY SCIENCE EDUCATION IN NORTHEAST THAILAND

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Sponsored by
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Science Lab Activities for Secondary Science Education in Northeast Thailand

An Interactive Qualifying Project submitted to the faculty of
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ABSTRACT

This project was sponsored by the Office of H.R.H. Maha Chakri Sirindhorn's Projects to improve science literacy in rural Thailand. We designed and implemented three engaging and relevant laboratory activities to interest students in science and develop laboratory learning in the Sakon Nakhon province of Thailand. The result was improved student engagement in science. The final product of this project was a lab manual to serve as a guide for teachers to develop and implement lab activities.

ACKNOWLEDGEMENTS

Our team would like to thank our sponsor, the Office of Her Royal Highness Princess Maha Chakri Sirindhorn's Projects, and our liaisons, Ajarn Nanthaporn and Ajarn Aphisit, for providing us with the opportunity to work on this project.

We would like to thank the teacher supervisor, Ajarn Prapatsorn, and the teachers of the Baan Muang Wittaya and Baan E-Kud schools for their warm hospitality and their assistance with the project.

We would also like to thank our liaisons from Chulalongkorn University, Ajarn Siripastr for her guidance in this project.

We would like to thank our advisor from the Chulalongkorn faculty of science Ajarn Supawan for her advice and feedback on the project and report

Finally, we would like to thank our advisors from Worcester Polytechnic Institute, Professor Demetry, Professor Golding, and Professor Vaz for their assistance throughout the project and their feedback during the report's drafting stages.

EXECUTIVE SUMMARY

The advancement of scientific literacy is an important goal of any country seeking to improve its economy, public health, or environment (Durant, 1987; Walberg, 1991; Caldwell, 1992). Economic and environmental concerns are especially pressing in the northeastern region of Thailand, where 17% of the population lives below the poverty line and deforestation is a major problem (NESDB, 2006; Dilokpatanamonkol, 1987). Improving science education may help alleviate these problems, as the scientifically literate are more competitive in the job market and may be more environmentally conscious.

Science education is not currently emphasized in the northeast; a study by Camfield and Darunee (2006) found that the educational system in the northeast of Thailand was extremely limited and focused primarily on vocational training rather than general education. In addition, many schools in the northeast still use traditional rote teaching methods despite national reforms promoting more active forms of learning (Puacharearn *et al*, 2004). However, knowledge of science is an important part of science literacy, and active teaching methods such as lab activities can be useful in imparting knowledge (Benware, 1984; Subcommittee on Research and Science Education, 2007). Therefore, in order to increase science literacy in northeastern rural Thailand, we were asked to develop three science lab activities by our sponsor, the office of HRH Princess Maha Chakri Sirindhorn's Projects.

The goal of this project was to provide the Baan Muang Wittaya and Baan E-Kud schools of the Sakon Nakhon district of Thailand with three engaging and relevant science laboratory activities for use in the normal curriculum. In addition to being engaging and relevant to students' lives, the labs were designed to be low-cost and of an appropriate difficulty level for the students. After a testing and modification process, the labs were compiled into a lab manual for distribution to other schools in rural Thailand. This lab manual included all three of the labs we designed as well as a section on designing lab activities, so that teachers could develop their own lab activities.

LABORATORY DEVELOPMENT

We established four criteria to develop the labs. These criteria were:

- *Engaging and hands-on*: The Literature suggests that in order to engage students in science, the lab activities should include student participation as opposed to simple demonstration.
- *Follows curriculum and appropriate difficulty level*: Because our sponsor indicated preliminary lab topics relevant to the curriculum (see Appendix B), our group chose labs related to these topics and tailored the difficulty of each lab to the appropriate grade level.
- *Relevant to students' lives*: In order to increase student interest and engagement, we decided that lab activities be relevant and applicable in students' daily lives.
- *Inexpensive and easy to implement:* We designed the lab activities so that they could be implemented at many schools and without our assistance. Therefore, we provide clear, easy to follow instructions and require materials that could be found locally.

The labs that were developed to fit the four criteria were as follows:

- **Biotechnology Board Game (Matthayom 1)** Designed to teach students about the applications of biotechnology in farming, this lab consisted of a board game in which students simulate growing crops using various technologies to enhance their yield.
- **Groundwater Lab (Matthayom 2)** In this lab, students build a groundwater flow model and use the pH scale to gain an understanding of the importance of keeping groundwater from being contaminated.
- **Battery Lab (Matthayom 3)** The basics of electric circuits and electrical safety are introduced in this lab through the construction of a battery from household materials.

LAB IMPLEMENTATION AND ASSESSMENT

These three labs underwent testing and revision before implementation in the classroom. Initial tests revealed several areas for improvement. The labs were modified by the team with additional comments and suggestions from the teachers at both Baan Muang Wittaya and Baan E-Kud schools. Once modified the labs were re-tested before classroom implementation.

After implementing the labs we used several assessment methods to analyze their impact on the schools. The assessment was intended to examine how engaging, interesting and relevant the labs were for the students and also to determine how useful and replicable the labs were for the teachers. The assessment methods consisted of surveys and focus groups with the students and interviews with teachers. We later used the data from this assessment as well as our own observations to analyze the effectiveness of the lab activities in meeting the project goal.

DISSEMINATION

The final step in this project was the dissemination of the lab activities to the Kusuman district of Sakon Nakhon. This was accomplished through two methods: a science education fair for teachers and students, and a lab manual for distribution to teachers. The education fair was a day-long event that consisted of demonstrations of our lab activities for teachers and engaging science activities for students. The lab manual is a document for distribution to teachers that includes instructions for developing new labs and for implementing the three labs developed by our team. Both methods were intended to increase the impact of our project in the Kusuman district by involving teachers from schools that were not directly affected by our project.

ANALYSIS

In order to determine the effectiveness of our activities in meeting the project goal, we analyzed the data collected during the assessment stage. The analysis consisted primarily of reviewing data such as student surveys and focus groups as well as teacher interviews. It also incorporated our individual observations and informal interactions with teachers and students. The analysis was used to evaluate not only our individual lab activities, but also the impact of our project as a whole on science education in the Baan Muang Wittaya and Baan E-Kud schools.

Our analysis of the lab activities showed that they shared several common aspects:

- **Time** Because labs often took a full two-hour class period to complete, teachers did not have sufficient time to explain concepts or administer questions. In some cases labs took multiple class periods to complete.
- **Background knowledge** Although the labs fit the curriculum, they did not coincide with the lessons being taught at this time of year. As a result, students did not have sufficient knowledge to answer questions confidently and correctly.
- **Student engagement** Students appeared engaged by hands-on components of all three lab activities. However, students lost interest during the final sections of the labs, which included questions and explanations.
- **Teacher reactions** Teachers reported that the lab activities were educational and that they would continue to use them in the future. Reasons for continued use included relevance to students' lives and increased student interest.
- **Confidence** Students appeared to lack confidence in their abilities and needed encouragement during lab activities. Many students copied the work of their peers.

CONCLUSIONS AND RECOMMENDATIONS

Based on the findings from our analysis, we developed several conclusions and recommendations. These conclusions are intended to provide a perspective on the impact of lab activities on science education and science literacy. Similarly, our recommendations are intended to reflect our perspective on the project's impact and how best to improve it.

Our conclusions are as follows:

- **Improving science literacy was not an achievable short-term goal** The effects of individual lab activities on science literacy are not measurable. It is unreasonable to conclude the improvement of science literacy from the results of this project.
- **Students were engaged by hands-on learning** Compared to engagement observed during a normal class period, students appeared more engaged by hands-on lab activities.
- **Students were most interested by lab activities that were relevant to their lives** Students reported that they were most interested by the lab activities when they directly related to their lives, such as using pH to identify water.

- **Students struggled to express themselves** When asked to respond in short-answer format, students either wrote extremely brief answers or copied from their peers. Similarly, students needed encouragement to express their opinions in focus groups.
- **Teachers received labs positively** All teachers involved in this project said the labs were educationally valuable and that they would continue to use the labs in the future.

The conclusions we stated gave rise to several recommendations to further the goal of this project and the sponsor. We made recommendations for the Office of the Princess, teacher supervisors, and future laboratory development.

Recommendations for the Princess' Office:

- **The lab manual should be distributed to schools throughout the Kusuman district** In order to provide a means to implement laboratory learning and improve science education throughout the Kusuman district, we recommend that the lab manual be distributed to teachers in schools throughout the district.

Recommendations for Teacher Supervisors:

- **School curricula should incorporate more active learning methods** Because of its effects on student engagement, we recommend that schools incorporate more active learning methods such as laboratory learning.
- **Schools should be provided with additional teaching materials** A major limiting factor in teachers' use of previously existing lab activities was access to materials, and because students did not have adequate access to textbooks. We recommend that schools be provided with additional teaching materials such as lab materials and textbooks for loan to students.

Recommendations for Future Laboratory Development:

- **Incorporate visual aids into lab activities** Students seemed to struggle less at understanding the labs when they involved visual aids. We recommend visual aids be incorporated into lab activities.
- **Labs should be developed with time constraints** Teachers need time to explain the concepts and procedure of each activity and may not be able to finish some labs in a

single class period. We recommend that one of the criteria for lab development should be the time involved for the completion of each activity.

- **Develop lab questions in cooperation with teachers** Teachers understand the ability levels and educational needs of their students best. We recommend that researchers and educators work together to develop the questions for each lab.
- **Follow-up to find out if lab activities are still in use** Attempt to contact the schools to determine if the labs are still in use. This can serve to further research by revealing what was successful or unsuccessful.

CONTRIBUTIONS

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Rose Colangelo
Rose served as an editor for many sections of the report, formatting drafts of the report before submission. This editing focused on formatting, grammatical errors, sentence structure, and punctuation. Rose's primary field of research for the project was teacher development which provided information for the introduction and background sections of the report. During the field work portion of the project, Rose participated in cultural exchange activities and taught English classes at both schools.

Carol Okumura
Carol was responsible for compiling and formatting the final draft of the project. She also assembled concluding information from student surveys, teacher interviews, and student focus groups. During the field work portion of the project, Carol led cultural exchange activities by choreographing the folk dance and teaching English classes. Carol contributed in the writing and editing of several parts of the report, and prepared material for presentations.

Sean Patrick
Sean was responsible for the design of two of the lab activities: the Biotech Board Game and the Battery Lab. He researched and developed the procedure, materials list, post-lab questions and background information for two lab activities. He also contributed writing to several sections of the report, helping edit each section for flow and tone. Sean also participated in cultural exchange activities and taught English classes at both schools.

Elias Whitten-Kassner
Elias was an observer for the implementation of lab activities at both schools and the chief observer and developer of the Groundwater Lab. He researched and developed the procedure, materials list, post-lab questions and background information for the groundwater lab. Elias participated in cultural exchange events, such as playing sports with the students and teaching English classes. Finally, he developed the basic outline for the Lab Manual.

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Leu-Shyue Chen
Leu-Shyue served as a translator and coordinator with the teachers at Baan Muang Wittaya and Baan E-Kud. He solved problems faced in the lab implementations. He was the primary leader in Post-Lab Student Focus Groups and helped conduct the Student Surveys in Thai. In addition, Leu-Shyue’s ideas contributed to discussion which led to development of the Findings and Recommendations. Lastly, he worked on the teacher’s manual and translated it into Thai.

Veerada Thammasunthorn

Veerada Thammasunthorn was the chief translator for the group. She translated all the laboratory activities along with other documents such as the teacher lab manual. Val made several modifications to them as well. She conducted student surveys, teacher interviews, and student focus groups and served as the coordinator for events that took place during the group's stay in Sakon Nakhon. She also contributed to implementation of the labs, and writing and editing several sections of the report.

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INTRODUCTION

The improvement of science literacy is a vital objective for countries in an increasingly technological world. Problems such as poverty, public health, and environmental degradation can be reduced through an increase in science literacy, which can itself be increased through science education (Durant, 1987; Caldwell, 1992; Hurd, 1958). Educational reforms have been implemented in many countries worldwide and more recently in developing countries. In disadvantaged areas of these countries, however, cultural, economic, and other factors often inhibit successful reform (Fry, 2002).

Having only a primary education is no longer sufficient in a society increasingly in need of knowledge-workers (Fry, 2002). In 2002, agriculture represented only 13% of the Thai economy while the service sector had grown to 47% of the Thai economy, indicating an increase in the need for educated workers. Rie Atagi (2002) reported that Thai students spend less time in science and math instruction than students of many other countries meaning that the science and math education are key focus areas for improvement. However, according to a report by Gerald Fry (2002), Thailand's educational development has considerably lagged behind its level of economic development.

Even with the achievement of near-universal primary education, access and other inequities in secondary level education remain problems, particularly in northeastern Thailand. The Northeastern is the most disadvantaged region, with the largest population in Thailand—making it a high priority for educational reform (Fry, 2002). Not surprisingly, provinces that lag behind educationally have also been identified by the National and Economic Social Development Board (2006) as having the greatest number of villages with serious poverty. Fry (2002) states that the northeastern region tends to lag significantly behind other regions on all major socioeconomic indicators. Rote memorization and lectures continue to be emphasized by many teachers in the rural areas even though Thai educational reforms, such as those embodied in the National Education Act, encourage student-centered active learning (Puacharearn *et al*, 2004).

The Office of Her Royal Highness Maha Chakri Sirindhorn, a major supporter of the National Education Act and the sponsor of this project, believes that an introduction of science laboratory activities that are relevant to the student's lives is an effective method to improve science education in rural areas and thus improve equity and access in the rural northeastern schools. Science lab activities use hands-on, cooperative, inquiry, and constructivist learning techniques, collectively known as active learning techniques (Hofstein *et al,* 1982; Hofstein *et al,* 2003). Active learning has been shown to increase student interest in science in several studies (Bonwell et al, 1991; Fisher *et al,* 1997). In order to effectively implement active learning methods, teachers must be familiar and confident with these methods. International consultant Dr. Hitendra Pillay (2002) recommends that teacher education be practical and urges the use of diverse approaches to pedagogy such as active learning.

The primary goal of this project was to implement three engaging and relevant laboratory activities to engage and interest students in science and develop laboratory learning at the Baan E-Bud and Baan Muang Wittaya schools of the Sakon Nakhon province of Thailand. The labs were designed to: be engaging and hands-on, relevant to students' lives, follow the national curriculum, and inexpensive and easy to implement. By working closely with our group, teachers introduced these activities to students with little to no help from us, making sure they would be able to implement the labs without any assistance after we left.

One of our strategies was to build strong relationships and to exchange culture in order to aid implementation and analysis of the lab activities. After implementation, the labs were disseminated to the Kusuman district teachers and students. This was done through an educational fair, but in order to disseminate the project in a sustainable manner, we developed a lab manual to be distributed to the Kusuman district. We hoped by working with the schools and our sponsor, the Office of HRH Princess Maha Chakri Sirindhorn's Projects, to augment the current science curriculum in the northeast region of Thailand to include more laboratory activities. Our objective is to further students' interest in science education and by this means advance science literacy.

LITERATURE REVIEW

Thailand has a long history of promoting education and literacy, dating back to Buddhist monastic traditions, as well as a recent history of progressive education reform (Fry, 2002). However, some regions of Thailand are less fortunate than others in the extent and quality of their education. In the southern and northeastern regions of Thailand in particular, education is generally considered by residents to be of poor quality, and is of a vocational rather than a general nature (Jongudomkarn & Camfield, 2006). Improving the general education system of the northeastern region, and in particular the science education system of that region, is the goal of our sponsor, HRH Maha Chakri Sirindhorn's Projects Office.

In this chapter, we will first describe some general problems faced by northeastern Thailand, in order to provide context for our project. We will then outline the importance of science education in resolving some of these problems. Next, we will discuss methods of science education and how to improve science education by implementing these methods. Finally, we will explain the role of teachers in implementing effective science education methods, and conclude with a discussion of previous efforts to improve science education in the northeast.

PROBLEMS FACED BY NORTHEASTERN THAILAND

Development in Thailand is unevenly distributed. While urban areas such as Bangkok have flourished economically in recent years, rural areas such as the northeastern provinces of Thailand have seen less significant improvement (World Bank Survey, 2005). The northeastern region of Thailand (**Error! Reference source not found.** comprises a third of Thailand's total area, and yet is also Thailand's most economically underdeveloped region. Although poverty has decreased throughout Thailand over the last 20 years, the northeastern province of Sakon Nakhon (Figure 1 - Regions of Thailand (International Affairs Faculty of Commerce and Accountancy, 2008)) continues to be one of Thailand's most poverty-stricken areas.

Figure 1 - Regions of Thailand (International Affairs Faculty of Commerce and Accountancy, 2008)

Poverty in Thailand is measured by using the concept of the poverty line, which is the income level determined to be sufficient for an individual to enjoy society's minimum standards of living. About 3.65 million people live below the poverty line in the northeast – more than half of the 7 million people living in poverty in Thailand (NESDB, 2006). This means that 17% of the population in the northeast lives below the poverty line, as opposed to 5% in Bangkok.

As shown in Figure 2 - Percentage Living Below Poverty Line in Thailand by Province (World Bank Survey, 2005), the proportion of people living below the poverty line in the Northeast has declined substantially since 1988 but still remains substantially higher than in the capital, Bangkok (circled blue). Sakon Nakhon (circled yellow) is one of the areas most affected by poverty, with more than 14% of the population living below the poverty line. This is partially due to the fact that, unlike Bangkok, Sakon Nakhon's population relies mainly on agriculture rather than industry or commerce to earn income.

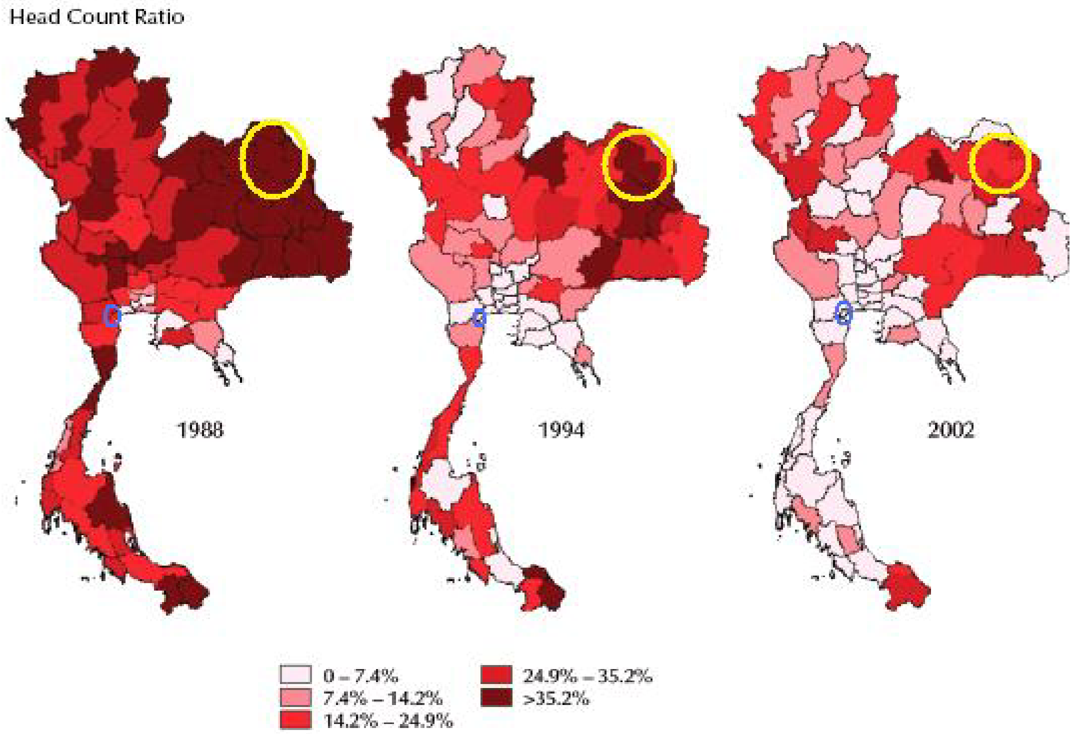

Figure 2 - Percentage Living Below Poverty Line in Thailand by Province (World Bank Survey, 2005)

Agriculture is the main source of income in the Northeast, but many environmental problems, such as salinization, erosion, and drought, have contributed to extensive rural poverty. Roughly one-third of the land in Northeast Thailand is unsuitable for agriculture. Though environmental issues such as flooding and drought are difficult to avoid, other issues such as deforestation and soil erosion can be mitigated through land-use and other controls. Parnwell (1988) points out that modifying people's attitude towards the environment is difficult, especially when economic pressures may encourage populations to pursue agricultural activities that are unsustainable. Because of this, Parnwell (1988) argues that it is more effective to increase environmental awareness at an early age, before these pressures are overwhelming.

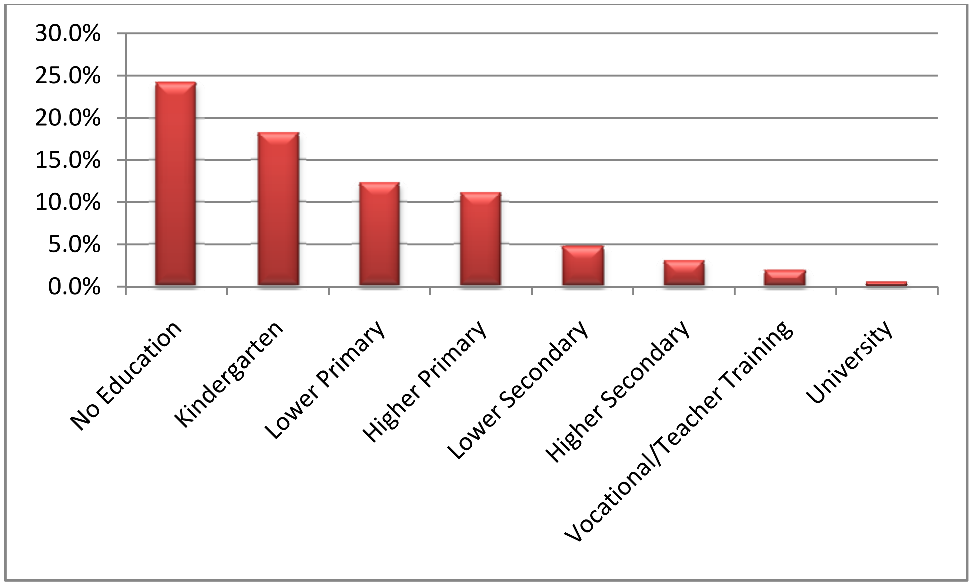

Figure 3 - Percentage of People below Poverty Line by Level of Education (NESDB, 2006)

The dual issues of environment and economy faced by the Northeast are compounded by the limitations of the educational system. Most poor people in Thailand receive little or no education despite compulsory primary and lower secondary education (NESDB, 2006). Figure 3 - Percentage of People below Poverty Line by Level of Education (NESDB, 2006) shows the percentage of Thai people living below the poverty line in each level of education – for example, 24.2% of people with no education live below the poverty line. Notably, there is a reduction of people living below the poverty line from 12% to 5% upon completion of lower secondary school (the equivalent of a 9th grade education in the U.S.). Camfield and Darunee (2006) found that the educational system in the Northeast was limited and focused primarily on vocational training and the improvement of occupational skills such as rice farming (Camfield and Darunee, 2006). One major objective of this project – and an objective of our sponsor – is to improve the quality of general education in the Northeast, especially the quality of science education.

THE IMPORTANCE OF SCIENCE EDUCATION

Although a general education in the liberal arts is important to the culture of any society, an education in science is crucial in an increasingly technological world, as was pointed out in a classic paper by John Durant (1987). Aside from accelerating the future advancement of science and technology, providing students with a good education in science has practical benefits such as improving economic conditions and public health. It has been argued, for example, that a good background in science provides a competitive edge in the job market, and that a background in science allows the individual to make more informed decisions about health issues such as diet, exercise, and hygiene. (Durant, 1987; Walberg, 1991).

In addition to the immediate concerns of public health and economy, all nations face long-term environmental concerns. The northeastern region of Thailand in particular faces several major environmental problems, such as deforestation, that may have a negative impact on the region's agriculture (Dilokpatanamonkol, 1987). Caldwell (1992) argues that knowledge of science is important in environmental decision making; however, improving science literacy alone is not a solution, as studies have shown there is no direct correlation between general science literacy and interest in environmental issues (Jenkins, 2003). Nevertheless, Jenkins (2003) suggests an introduction of the scientific perspective on the environment in conjunction with the social and political perspectives during early education as a remedy to environmental apathy, and encourages students to "ask appropriate questions and search for answers," an approach which goes hand in hand with inquiry-based science education.

The level of literacy is often used as an indicator of the general level of education in a country or region. Similarly, a measure of science education is the level of *science literacy.* The term science literacy, originally coined in 1958 by Paul Hurd (1958), has since then taken on a number of different meanings. Science literacy can be broadly defined as a practical appreciation for the strengths, limitations, methods, and important discoveries of modern science. It may also include an appreciation for scientific decision making and ethics (Sadler, 2004).

Science literacy is first and foremost the understanding of science. This is mainly constituted of a familiarity with the scientific method and the nature of science, which may encapsulate the notions of testable hypotheses, the importance of empirical data to confirm or reject a hypothesis, and the non-absolute nature of scientific theories. An understanding of science may also include a familiarity with the philosophy of science - for example, the importance of skepticism and pragmatism in scientific investigation. A familiarity with major scientific discoveries such as germ theory is also a component of science literacy, although an understanding of the foundations of science is more often considered an important measure of science literacy (Pella *et al.*, 1966).

Hurd and Gallagher (1969) argue that a person literate in science should not only be familiar with key concepts such as the scientific method and skepticism; he or she should also be familiar with the social dimensions and responsibilities of science, including the impact of science on culture and modern problems facing society. Understanding the interrelationship between science and society – the importance of science in social decision making and ethics, and the importance of ethics in science – is a major component of a basic scientific education (NSTA, 1964; National Research Council, 1996).

The improvement of scientific literacy is an important goal of any country seeking to improve its economy, public health, or environment (Durant, 1987; Walberg, 1991; Caldwell, 1992). However, it is important to note that no direct correlation has yet been shown between the improvement of science literacy and the improvement of societal concerns. In the case of science literacy and environmental awareness a definite lack of correlation has been shown (Jenkins, 2003). Despite this lack of hard evidence, science education is widely regarded as a "Good Thing" (Durant, 1987) and science is generally considered an important part of childhood education, as evidenced by the introduction over the last century of science curricula into elementary and secondary school programs throughout the world.

Although it is possible to improve science literacy in adults, it is generally easier to instill the understanding of science in younger students (Hacker, 1992). By adulthood, most people have developed their own personal beliefs and beliefs imparted by their culture, making it difficult to introduce new ideas (Brown *et al*., 2005). Lewin (1992) supports this claim by stating that it is necessary to impart science literacy in young children, because it is more difficult to improve science learning in older students who are ill-prepared by their early education experience.

ACTIVE LEARNING IN SCIENCE EDUCATION

Effective education requires effective teaching methods, and improving science literacy is no exception. Our research focused on methods of active learning rather than passive learning, since our project involved lab activities, which are inherently active. Active learning seeks to engage students and encourage them to think about what they are doing rather than passively listening to a lecture (Bonwell *et al*., 1991). Some studies have shown an improvement in conceptual learning using active learning strategies (Benware, 1984), but there is also evidence that there is no significant difference in academic performance between some active and passive learning strategies (Haidet, 2004). We analyzed several learning methods that were forms of active learning. Of the methods we assessed, cooperative, constructive, hands-on and inquiry-based learning methods had the greatest weight of evidence for improving students' learning capabilities in science.

Lapp *et al.* (1989) presents *cooperative learning* as a group-oriented style of learning. Typically, any classroom has students with different levels of ability and it is often hard for educators to tailor their teaching to each individual. As a result teachers will generally teach to the middle of the class as a way of balancing the skill levels of students. In this situation, some students will become bored because they understand the material and others will become lost and lose interest because the material is too difficult. By dividing students into small groups with individuals of differing abilities, students can learn from one another and each student is more likely to participate, according to Lapp *et al*. (1989).

Constructivist learning is based upon students learning via their understanding of natural phenomena rather than having scientific experts' reasoning presented to them (Lewin, 1992; Cooperstein *et al*, 2003). It has been observed that young students have their own "common sense" beliefs about natural phenomena (Lewin 1992). According to a study by Lewin (1992), even when they are told the facts directly, many students still retain their old underlying beliefs without visual and/or tangible proof to the contrary. Students can be led to the accepted beliefs about these natural phenomena through activities that allow students to develop accurate conclusions (Lewin, 1992; Cooperstein *et al*, 2003; Bilgin, 2006; Puacharearn *et al*, 2004). This way, students' beliefs are incorporated with the accepted scientific theories.

A review of multiple studies by Bilgin (2006) concluded that the science classroom is one of the best places to incorporate *hands-on learning* in the school. Bilgin (2006) defines hands-on learning as "engaging learning activities, using all possible senses, and reaching a conclusion." Many students are considered to be active learners, which means they learn better when actively participating (Bilgin, 2006; Bonwell *et al*, 1991). Research studies using statistical analysis reported that hands-on science programs significantly improved elementary science students' achievement, process skills development, and attitudes toward science (Byun, 1985). Bilgin (2006) concludes that hands-on learning activities performed by students are more efficient for learning than demonstration.

Inquiry-based learning involves students understanding the world through asking questions and seeking answers to these questions (Chiappetta, 1997; McBride *et al*, 2004; Wallace *et al*, 2004). Since science is fundamentally based on answering questions about the world, inquiry-based learning lends itself to science education. Inquiry-based education reform has been implemented in China, and inquiry is a theme of science education around the world (Pepper, 1986; Zhang, 2004).

There is speculation as to whether these relatively new learning methods are actually better. For example, in an account from a Chinese chemistry class, students who originally weren't interested in science showed improvements when active learning was introduced (Zhang, 2004). However, other studies showed little difference in the grades of students in an inquiry-based system compared to a textbook and lecture oriented classroom (Pine, 2005; Haidet, 2004). Active versus passive learning continues to be a controversial issue in the academic world. However, many countries in the West (as well as an increasing number in the East) incorporate active learning into their science curricula, and incorporating active learning through lab activities is an objective of the current Thai education reform (Fry, 2002).

Our project is specifically aimed to improve science education through science laboratory activities. Science lab activities are considered an integral part of most science classrooms in the U.S. (Fisher *et al*, 1997). Science laboratory activities are designed to have the students actively engage in their learning. Students who perform labs may understand more because they are experiencing science first hand (Subcommittee on Research and Science Education, 2007). Different active learning methods, such as inquiry, constructivism and hands-on learning, are often effectively incorporated into laboratory activities (Hofstein *et al,* 1982; Hofstein *et al,* 2003).

Science labs are intended to promote scientific thinking and improve understanding of scientific concepts such as the scientific method (Hofstein *et al,* 1982). The scientific method comprises four principal elements according to Wolfs (1996):

1. Observation and description of a phenomenon or group of phenomena.

2. Formulation of a hypothesis to explain the phenomena. In physics, the hypothesis often takes the form of a causal mechanism or a mathematical relation.

3. Use of the hypothesis to predict the existence of other phenomena, or to predict quantitatively the results of new observations.

4. Performance of experimental tests of the predictions by several independent experimenters and properly performed experiments.

By formulating hypotheses and testing them during a laboratory activity, students experience the scientific method firsthand. The laboratories that directly relate lecture material and theoretical components of the students' subject to real-world applications facilitate learning, according to the Subcommittee on Research and Science Education (2007) and Fisher *et al* (1997). In a study conducted in an Australian biology class the researchers measured the change in class's "cohesiveness, open-endedness, integration, rule clarity, and material environment" with a cross-nationally validated assessment called the Science Laboratory Environment Inventory [SLEI] (Fisher *et al,* 1997). The experiment found that laboratory learning affects students' attitudes toward science in a positive manner. The study also found that educators who integrate theoretical and practical work with laboratory activities are likely to encourage greater achievement among students (Fisher *et al,* 1997).

Although claims have been made to support science laboratory activities in science education, there is a lack of evidence to show how effective science labs are for improving science education (Hofstein *et al,* 1982; Hofstein *et al,* 2003). The majority of studies have failed to show that science lab activities have measurable impacts on learning (Hofstein *et al,* 2003). Hofstein (2003) claims that sufficient time and opportunities for interaction and reflection increase the effectiveness of laboratory activities. However, many of the studies that show science laboratory activities having negative or no effect on learning often did not provide sufficient time and opportunity for interaction and reflection (Hofstein *et al,* 2003). Hofstein claims that if the studies were done again but allowed sufficient interaction and reflection there would be more positive results. Although increasing the time and opportunities for laboratory learning is helpful, educators find it difficult to devote time to laboratory activities and balance their lesson plans (Hofstein *et al*, 1982; Hofstein *et al*, 2003).

THE ROLE OF TEACHERS IN ACTIVE LEARNING

There is a weight of evidence suggesting that teachers are the key to improving science education (Bilgin, 2006; Puacharearn *et al*, 2004; Lapp *et al*, 1989; Brown *et al*, 2005; Lewin 1992). Unfortunately, there is a lack of science-trained personnel at secondary schools throughout the world (Lewin, 1992). Notably, lack of teacher education in active learning methods affects teacher confidence, an important factor in effective education, when teachers are asked to implement active learning in the classroom (Yu, 1991; Appleton, 1995). Because some teachers may be unfamiliar with active learning methods, properly introducing active learning before asking them to implement it in the classroom can help facilitate teacher confidence.

Implementing laboratory experiments in a Thai classroom may not only require educating the teachers to use active learning, but also demonstrating how active learning works and giving examples of how it can be done. Guskey (1986) and Bolster (1983) found that change in methods is more likely to persist when teachers are able to practice new methods. According to Fry (2002), because of a lack of innovative and international teaching resources (training, books, etc.) as well as overly theoretical teaching methods, it may not be possible to alter classroom practices in Thailand simply through teacher instruction or demonstration. A study by Brown (2005) concluded that a viable strategy to promote change is to get teachers engaged in inquiry-based research science experiments themselves.

Research studies have shown that conducting inquiry-based science workshops is an effective way to impart inquiry techniques to science teachers (Brown, 2005; McBride, 2004). In these workshops, teachers are asked to discuss a traditional laboratory activity that their students may perform, and to postulate questions about it. Then, in learning groups, the teachers would perform the labs together to seek answers for their questions as their students would. Once all of the learning groups have come to a conclusion, they would discuss them together (McBride, 2004).Through this process, the teachers will experience the same type of learning that they will provide to their own students (McBride, 2004). This activity should generate questions that challenge currently accepted science concepts, extend the teachers' understanding of those concepts, and encourage the teachers to explore differing interpretations of science phenomena (McBride, 2004; Chiappetta, 1997).

Because of our short time frame and limited expertise, offering a science "workshop" to the teachers we will be working with is not practical. It is, however, feasible for us to do a run-through of our lab activities with the teachers, and thus aid them in successfully implementing an active approach to these activities. This run-through is also intended to extend the impact of our project, so that teachers are able to use the laboratory activities without our assistance in the future. However, our on-site findings regarding a similar effort (Amendolare *et al.*, 2008) indicated that sustaining our project's impact would be difficult, and depended on some factors other than teacher involvement.

SCIENCE EDUCATION INITIATIVES IN THE KUSUMAN DISTRICT OF SAKON NAKHON

Previous efforts have been made to introduce active learning in rural Thailand. In 2008, students from Worcester Polytechnic Institute introduced lab activities at the Kusuman Wittayakhom school in Sakon Nakhon (Amendolare *et al*., 2008). Communication with the teachers involved in the 2008 project provided us with some feedback on how to improve the success of our project.

Of the four lab activities introduced by the previous IQP, only one is still in use as of January 2009. Teachers indicated that the other labs were no longer being used for a variety of reasons, including difficulty level and conflicts with the curriculum. In order to avoid these problems, teachers suggested that lab activities be designed to be flexible, relevant, and of an appropriate difficulty level. (Moon & Uapipatianakul, 2009).

Upon arrival in Sakon Nakhon, our interactions with the teachers and observation of the schools gave us new insight on the status of science education at the two schools. Class sizes at both schools were smaller than our initial estimate of 50 students – classes were between 20 and 30 students, partially due to absenteeism. Many students are of the So or Laos ethnic groups, which both have unique languages (Personal communication with teachers, 2009).

There is a lack of teachers at both schools – at Baan Muang Wittaya, there was only one Matthayom (middle school) level science teacher, and at Baan E-Kud there was no science teacher due to the recent transfer of the sole Matthayom level science teacher. To replace the science teacher at Baan E-Kud, three teachers from other subjects had volunteered to teach science classes, one for each level. However, these teachers were not trained to teach science, but rather other subjects (Personal communication with teachers, 2009).

The challenges faced at these schools are representative of science education throughout the northeast. northeastern Thailand faces several problems which may be partially alleviated in the future by improving science education. The focus of this project is the application of cooperative, hands-on and inquiry-based learning methods in order to engage students. We hope to engage teachers as well as students in these activities, and to introduce teachers to teaching methods other than rote memorization. These methods will be manifested in laboratory activities designed to be relevant to issues faced by the students in their everyday lives.

METHODOLOGY

The primary goal of this project was to implement three engaging and relevant laboratory activities to engage and interest students in science and develop laboratory learning at the Baan E-Kud and Baan Muang Wittaya schools of the Sakon Nakhon province of Thailand. There was also an integrated goal of building relationships with students and teachers through cultural exchange activities and daily interaction. To improve the results of our project, we built relationships with teachers and students to improve comfort and cooperation between the team and the schools.

In order to accomplish our primary goal, we developed four main objectives:

- *Science Lab Activities Development*: A preliminary set of laboratory activities was developed based on a set of criteria and through review of existing experiments.
- *Lab Implementation*: Once revised, the labs were introduced to the teachers and then had the teachers implement the labs in their science classrooms.
- *Lab Assessment*: For this stage, we refined the nature and content of the lab activities and assessed the impact of our labs. This was accomplished through teacher and student focus groups, interviews and surveys.
- *Lab Dissemination:* We disseminated our project findings to the teachers of the Kusuman District in an education fair and composed a lab manual to be given out to other schools who request it.

In addition, cultural exchange was integrated into the project. Cultural exchange was helpful throughout the implementation and assessment stages and greatly facilitated our progress. In this chapter, we will outline the process and rationale for each of our four objectives and conclude by discussing the cultural exchange involved in our project.

OBJECTIVE ONE: SCIENCE LAB ACTIVITY DEVELOPMENT

Because our project goal was to implement three engaging and relevant lab activities, we first sought to develop at least three lab activities that could be used. The development of three lab activities before coming to Bangkok created a foundation for our field work. By developing lab activities ahead of time we had a lot of time to modify and test the labs to ensure that they were labs that were worth implementing at the schools. The Office of the Princess provided our group with the national science curriculum for the Matthayom levels M1, M2, and M3 (see Appendix A). These are secondary education levels that are equivalent to a U.S Junior High/Middle School education (6th, 7th and 8th grade), and students complete them at age 15. One lab was developed for each level.

Based on the National Curriculum, the 2008 Interdisciplinary Qualifying Project for science education in northeast Thailand, previous research on active learning and science activities, and the wishes of the Office of the Princess and teacher supervisor of Kusuman, we developed the following criteria to develop the science labs:

- *Engaging and hands-on*: Based on our research on active learning methods, lab activities that include student participation as opposed to demonstration engage students in science. Therefore, we designed the lab activities to use hands-on methods in order to improve student engagement.
- *Follows curriculum and of appropriate difficulty level*: Because the Office of the Princess and the Kusuman teacher supervisor specified preliminary lab topics relevant to the curriculum (see Appendix B), our group chose three labs related to these topics and tailored the difficulty of each lab to the appropriate grade level.
- *Relevant to students' lives*: In order to increase student interest and engagement, research specified that lab activities should be relevant and applicable in students' daily lives.
- *Inexpensive and easy to implement:* We designed the lab activities so that they could be implemented at many schools without our assistance. Therefore, labs that provide clear, easy to follow instructions and require materials that could be found locally were developed.

After research and thorough review of science experiments that had been developed in the past by reputable educational agencies, such as teachengineering.org or NSDL.org, we compiled three model lab activities and made our own changes based on the four lab criteria described above in order to adapt them for use in Sakon Nakhon. These activities were developed based on the curriculum given to us by the Office of the Princess (Appendix A), and inspiration for the labs came from example lab activities from educational websites and our own experience with science lab activities.

OBJECTIVE TWO: LAB IMPLEMENTATION

Our second objective was intended to familiarize teachers with the lab activities, test the lab activities in a school environment, and reveal problems with the lab activities. These steps were taken in order to implement the labs effectively at the Baan Muang Wittaya and Baan E-Kud schools. In addition, the implementation of the labs in a real-world setting allowed us to perform more meaningful evaluation of our project by using student and teacher input.

Before introducing the lab activities to the teachers, we tested each lab in order to make sure that lab procedure produced the expected results and to anticipate any problems that could arise in the classroom. If there was a problem with a lab, we made changes and retested the lab to be sure it still worked after adding modifications. We also used this step to help us to determine whether our lab activities had consistent results by attempting each lab multiple times to make sure the first success was not due to chance.

We introduced pre-lab student surveys before lab implementation to gain an understanding of student perceptions of science and establish a foundation for our research. Information gathered from this survey helped us assess student interest in science, as well as general perceptions and opinions of science, in order to determine the focus of our project. If students were mainly apathetic towards science, we determined labs should be modified to focus more on conveying the benefits of science education and improving student attitudes towards science, rather than on conveying information about a topic. Conversely, if students were already interested in science, the labs could focus more on the educational aspect. However, this does not mean that we would not have to strike a balance between student interest and educational value as we aspire to have both.

In order to assess students' perception of science, we developed a short survey (Appendix C) to be conducted before implementation of the lab activities. The survey consisted of five Likert scale questions and five short-answer questions. This approach gave us both a qualitative and quantitative perspective on student perceptions of science. The qualitative questions were intended to assess students' background and opinion of science, while quantitative questions were intended to assess interest levels and how relevant students perceive science to be to their lives. The surveys were conducted orally in Thai by the Chulalongkorn Students and the students at Baan Muang Wittaya and Baan E-Kud schools wrote their answers in Thai. The Chulalongkorn students then translated the survey responses into English. Once translated, the responses were analyzed by the group.

We realized there were going to be some barriers with the initial surveys since the students did not know us well during the first week. We felt the students may answer the questions with only positive answers because they thought they were being graded or because they didn't want to offend their teacher. We told the students that the survey was not a test and their teacher wouldn't see the results. We also had the teacher help conduct the survey since the students knew their teachers better than us. Another barrier was that the some students weren't good at writing in Thai since it wasn't their first language. For this reason, we had some Likert scale questions so that students who couldn't write Thai could still give us useful information.

The survey results were intended to reveal the students' feelings about science so we could modify the experiments accordingly. In order to explain to teachers what students initially thought of science and further justify lab usage, we obtained these survey results before introducing the labs to the teachers, and explained the results and analysis to teachers. This explanation was intended to help teachers understand their students better and to evoke feedback from teachers about students' perceptions of science.

We tested and explained the labs to the teachers at both schools. Doing this assisted the teachers in understanding what the labs were designed to teach and becoming confident in teaching the lab activities. Our intention when running through labs with the teachers using demonstration and interaction was to help teachers fully understand each aspect of the labs. The teachers often presented us with desired changes to the labs during the teacher introduction. We then made these changes and repeated the testing process. We presented the labs to the teachers a second time before they introduced the labs to the students so there wouldn't be any surprises when they implemented them.

Finally, we tested our lab activities in the classroom. This allowed us to draw data from a realistic environment. The teachers implemented the labs by themselves in class while we observed and assisted occasionally. Afterward, the teachers provided our group with feedback through the Chulalongkorn students on the quality of the activities. We encouraged the teachers to make recommendations for changes and sections they wanted to add to the lab based on how the lab went in their class. All of this feedback was used to help us improve our labs for our lab manual.

OBJECTIVE THREE: ASSESSMENT OF LAB ACTIVITIES

We assessed our lab activities using several assessment methods to develop an understanding for the actual impact of the labs. The assessment stage was intended to answer two questions about our project:

- How engaging and relevant are the lab activities from the students' perspective?
- How useful are the lab activities to the teachers for teaching science concepts?

The first part of our assessment (Appendix D) was specific to our lab activities, and was designed to answer the question of how engaging and relevant the labs were to the students. Because the labs were being implemented for the benefit of the students, getting feedback by directly surveying the students was constructive in the evaluation process. Most importantly, if our labs were not engaging or relevant to the students, we modified them.

The first five questions in the post-lab survey aimed to determine through a Likert scale system what the students thought of the lab in general. The last five questions were short answer questions that allowed students to describe in more detail their thoughts about the lab and give suggestions for improvements. The surveys also gave us useful information to include in the recommendations section of this report.

In addition to surveys, we also performed student focus groups after implementing the lab activities because this gave us student feedback on the lab activities. These focus groups were intended to expand upon some of the questions asked on the surveys, and to provide us with information about students' particular interests in science. During the focus groups, students discussed among themselves and built on each others' ideas. This information was relevant not only for our own purposes in assessing the labs, but also for any future researchers to use when attempting a similar project.

Our second assessment objective was to understand the teachers' opinions of our lab activities. Because the teachers will ultimately be the ones to implement labs in the future, they should understand the benefits of the lab activities and be comfortable with implementing the lab activities in the classroom. If teachers did not find our lab activities to be useful in their classroom, we addressed their concerns in our lab manual. The post-lab interview with the teachers (Appendix E) was concerned mainly with the teachers' perception of the lab for their students and how the labs should be improved in a way such that scientific concepts are more easily conveyed to the students.

The surveys, focus groups, and interviews were not conducted by WPI students because of the language barrier. We decided it was more effective to have the Chulalongkorn students conduct all of the assessments in Thai since the students and teachers at Baan Muang Wittaya and Baan E-kud schools were more comfortable responding in Thai. The Chulalongkorn students worked with a WPI student to translate the assessment data into English and compile it in an electronic file.

Some limitations for the surveys were that it was hard to translate some responses from Thai to English and some Matthayom students did not know how to express themselves well in Thai writing since it wasn't their first language. We also were aware that the students may not answer the questions honestly if they didn't like the labs. However, since this was the second survey we conducted and since we had engaged in cultural exchange activities and interactions with the students we felt they were more comfortable to answer truthfully about the labs.

There was a language barrier within the focus groups: because some students don't normally speak Thai amongst each other, the Chulalongkorn students could not record all the details of the focus group discussions. To overcome this barrier the Chulalongkorn students had to ask a lot of specific and direct questions of the students to gain the information that we wanted from the focus groups. Another limitation was that the students were shy to say what their impressions of the labs were. By positively interacting with the students through cultural exchange, we were able to make them more comfortable with answering the questions and discussing the labs openly.

We faced one major limitation with the teacher interviews. We weren't sure if the teachers would answer the interview questions about our labs honestly in fear of disappointing us. We stressed that we wouldn't be offended by what the teachers said and we also made sure that the teachers had a major role in producing and implementing the lab so that they understood that they had ownership of the labs and could make changes. Teachers appeared to become more comfortable expressing their opinions with us after having positive interactions through cultural exchange and eating lunch with us.

OBJECTIVE FOUR: DISSEMINATION OF LAB ACTIVITIES

For the dissemination of the project, we intended to help the educators of Kusuman district understand the purpose of the three labs and spread the use of laboratory learning throughout Kusuman district. There were two methods to meeting this goal. On February 16th, at the end of our 4th week in Sakon Nakhon, we collaborated with another group working in the Sakon Nakhon region to promote science literacy to organize an education fair for the secondary school teachers and students of the Kusuman district. The second dissemination method was the production of a lab manual.

The education fair was a direct interaction with teachers from the Kusuman district in an attempt to promote laboratory learning. During this fair each group set up three lab stations and five mini-lab stations in order to share our project experiences with the audience. The lab stations were intended to demonstrate our lab activities to the teachers of the Kusuman district. The students and teachers of our schools ran these stations to demonstrate and explain the labs to the other teachers of the Kusuman district. Teachers were able to discuss the reactions of the teachers and students who were introduced to the labs. This was intended to give a more convincing argument to using the labs than if we had tried to convince the Kusuman teachers of the benefits of our labs ourselves. The mini-lab stations were intended to interest and educate students on some science phenomena such as light refraction.

The lab manual was intended to allow teachers in the Kusuman district to have easy access to a permanent source of step by step procedures for the three lab activities introduced at Baan Muang Wittaya and Baan E-Kud Schools. It also gave instruction to teachers to assist them in creating their own lab activities. To encourage effective lab activities, we emphasized the lab criteria we used to design our three labs. Finally, the lab manual was translated into Thai by the Chulalongkorn students to improve accessibility for the teachers.

ANALYSIS AND FINDINGS

In this chapter, we present findings based on our work developing and implementing science laboratory activities in Sakon Nakhon. First, we will describe our findings from assessments done prior to lab implementation. We will then present a description and analysis of each lab activity that we implemented. Finally, we will discuss the general findings of the project.

INITIAL FINDINGS

Using data collected through student surveys and discussions with teachers, we were able to draw several conclusions about students' perceptions of science prior to the implementation of the lab activities. The findings from our initial assessment served as a foundation for our research, providing us with data about students' existing science background and interest in science. These findings served as a basis for comparison with post-lab student survey and focus group data, and were used to determine whether our project had an effect on student interest in science.

Our initial findings are as follows:

Many students lacked commitment to school. Teachers reported that many students only attend school until lunch and then skip afternoon classes, indicating a lack of student commitment to education. Teachers at both schools also informed us that absenteeism was common, a claim that was supported by findings from our classroom observations. From these findings, we concluded that student apathy was a problem among the Matthayom levels.

Many students do not have the opportunity to continue their education. About one third of the students in the Matthayom 3 classroom at Baan E-Kud School would continue on with their education (Personal communication with teachers, 2009). It was reported by teachers at both schools that many families weren't able to afford their child's education—forcing students to immediately start working after completion of compulsory education.

Students expressed a desire to learn about science. Despite our findings that student interest in education was low, initial lab survey results showed that students were interested in science and wanted to learn more about it. Students especially expressed an interest in lab activities, and many listed lab activities as a reason for enjoying science class (Appendix G). However, it should be noted that there may be a bias in our results inherent to the nature of the surveys – absent students did not contribute their input, and students who did show up at class may have been more interested in learning. Despite this potential bias, we concluded that students were enthusiastic to learn about science, especially through lab activities.

Students enjoyed classes that were related to their lives. When asked about their favorite subject, many students responded that it was “career and technology”, because it related to their lives and was engaging. Although only a few students responded that science was their favorite subject, those who did list science as their favorite subject said that they enjoyed science because of lab activities and relevance to their lives. From these findings, we concluded that relevance to students’ lives was an appropriate criterion in the design of our labs.

Students struggled to express themselves. Our last finding from initial assessments was that students seemed to struggle when writing short answers on surveys, writing only the bare minimum and seldom explaining their answers. Teachers reported that many students struggled with short answers on exams as well. Students’ reticence to write may have affected the results of our assessments, as some students copied from each other rather than filling out their own answers.

BIOTECHNOLOGY BOARDGAME LAB ACTIVITY FINDINGS

Agriculture is the main source of income in northeast Thailand. According to our initial findings, many students start working to help their families’ income at young age. Therefore, our sponsors recommended the topic of biotechnology in food production to be introduced for the Matthayom 1 level (Appendix B). The biotechnology board game is a laboratory activity created in order to convey this knowledge to students.

In the biotechnology board game, students take on the role of a farm overseer and decide how to develop their farms and which crops to grow (Appendix M). The objective of the game is to make as much money as possible, so choosing the correct strategy to make money is important. In the end, students compare strategies to see which worked and hypothesize how they could change their strategy to win next time.

The game is designed to show students the difference between organic and genetically modified crops, along with the importance of investment in items such as irrigation and fertilizers. By managing their own money and buying different items, students make investment decisions in order to yield best crop results. Other farm improvements such as silos and greenhouses are also introduced in the game.

BIOTECHNOLOGY BOARDGAME LAB MODIFICATIONS

Trials of the game were conducted with and without the teachers. These trials allowed us to modify original rules and implement new ones based on group discussion and teacher recommendations. Visual aids such as a game board, game pieces, and paper money were created in order to make the game more interactive.

The science teacher at Baan E-Kud also requested minor modifications in the rules. He believed the board game did not emphasize the importance of investment in items such as organic seeds and silos enough. He also wanted a modification of the rules to increase the incidence of farmers going bankrupt, which he believed was a realistic concept to show the students.

BIOTECHNOLOGY BOARDGAME FINDINGS

Post-lab assessment done after implementation of the biotechnology board game activity allowed us to draw findings specific to this lab. These included post-lab student surveys, teacher interviews and student focus groups.

The biotechnology board game was relevant to students' lives. It was reported by the science teacher at Baan E-Kud school that within a short period of time (one two-hour class period), this activity allowed students to experience events that would extend over a period of several years in real life (Appendix H). Students also claimed this lab was relevant to their lives, as their parents grew crops as a source of income (Appendix J).

Several game rules for the board game lab activity were too complex. Post-lab assessment results suggested (Appendix H) that some concepts of the game were too detailed and difficult for students to grasp. The science teacher at Baan Muang Wittaya proposed a solution to improving the comprehension of the rules (Appendix H), by first introducing the game to a small group of students, who would then explain it to the rest of the classroom. As a group, we decided to make several rules of the game *optional rules* (Appendix M) as a means of simplifying the game. This modification also allows teachers to customize the game to teach concepts they feel are important for students to learn.

Students struggled when trying to develop their own strategy. The biotechnology board game required students to make investment decisions in order to earn the most money. Many students did not vary their strategy throughout the game, or they simply copied the strategy from another classmate. Our initial findings suggest that this problem may have arisen from lack of student confidence.

GROUNDWATER LAB FINDINGS

The population of the Kusuman district of Sakon Nakhon relies heavily on groundwater, especially during the dry season. With that in mind, the groundwater lab is designed to emphasize the importance of preventing pollutants from entering the ground, as well as the way groundwater flows. This activity also shows students, through pH testing, how safe their groundwater sources are. This lab uses active learning methods and is aligned with the national curriculum for *earth and earth changes* for Matthayom 2 students (Appendix B).

The groundwater lab consists of four parts: permeability, groundwater model, pH testing, and measuring pH in local water sources (Appendix M). In part 1, the permeability lab, students measure the permeability of gravel, soil, and sand. In the groundwater model lab, part 2, students design their own groundwater system with two wells and observe the flow of groundwater. Students then add food coloring to their model in order to visualize how pollutants flow through groundwater. In the pH testing lab, part 3, students test various liquids with pH paper to discover which are acidic and which are basic. Finally, in part 4, students measure the pH of water collected from their surroundings: purified water, tap water, and pond water. Students were also asked to fill out handout exercise questions in groups during the experiments (Appendix M).

GROUNDWATER LAB MODIFICATIONS

The science teacher at Baan Muang Wittaya made several suggestions to make this activity more relevant to students' lives. She created a large scale filtration model in order to show students how the ground acts as a water filter. A few students later reported (Appendix J) that they had already built a similar filtration device at home. The science teacher also suggested the pH water test to be done with water students brought from home in order to engage them in the activity, as well as increase awareness. Furthermore, minor adjustments to the procedures were changed to allow a good representation of real life situations. For example, colored water was poured directly on the model instead through the straws. Students were also given litmus paper along with universal pH indicators in order to learn about their usage as well as their differences.

GROUNDWATER LAB FINDINGS

After the groundwater lab was implemented, we drew our findings based on the post-lab assessments that included post-lab student surveys, teacher interviews and student focus groups.

Students displayed more interest and engagement with part two of the lab. We discovered through student surveys and focus groups that students expressed a liking for part 2, while some disliked parts 3 and 4 (Appendix I and J). The science teacher from Baan E-Kud also voiced her concerns about the second half of this experiment. She said that this half of the experiment was not as interactive and hands-on as part 2 (Appendix H). Additionally, students stated during focus groups that they prefer learning through experiments as opposed to reading and answering questions in class (Appendix J). With these findings, we concluded that hands-on methods are an important criterion in designing and implementing lab activities to engage and interest students.

Teaching strategies had varied effects on the lab implementation. This lab was performed during two-hour class periods. The science teacher at Baan Muang Wittaya was able to complete all four parts of the lab activity during a two-hour classroom. However, for the same two-hour class length, the science teacher at Baan E-Kud was only able to perform *one* of the four parts of the lab in a two-hour period. The Baan E-Kud teacher spent time explaining the background information for the lab. This inconsistency led to some difficulties for the team when trying to figure out specific details such as lab length for the lab manual. From this, we concluded that lab times in the lab manual are approximate and may vary.

The lab took too long to implement. Teachers reported during interviews that this lab activity can be broken down, since it contains many parts (Appendix H), to reduce the time necessary to complete it. Short labs were preferred so the teachers could lead class discussions or ask questions. We concluded that this lab should be broken down into smaller parts, with a possible removal of parts 1 and 3 which both provide students with similar concepts as parts 2 and 4.

BATTERY LAB FINDINGS

The battery lab was designed to educate Matthayom 3 students on the basics of electrical safety, and the components required to create a functional electrical circuit. Although most students won't analyze electrical circuits in their daily lives, the concepts of voltage and current are applicable to any situation involving electrical power—vocational or domestic. Furthermore, circuit analysis reinforces algebraic problem solving skills, which can be applied to everyday situations. The battery lab supports the national curriculum for Matthayom 3 students along with an engaging experience with electricity.

There are two interactive parts to the battery lab (Appendix M). In part 1, students lit a light-emitting diode, or an LED, by using lemons, copper, and zinc. In part 2, students generate an electrical circuit by building a voltaic pile out of copper, aluminum foil, and paper towel soaked in salt water. Toward the end of the lab, students were given a set of exercise questions related to the lab activity (Appendix M). These questions concerned the application of Ohm's Law (V=I * R). Two variables were given along with a diagram of the electrical circuit, and students were asked to determine the third unknown variable using the given equation.

BATTERY LAB MODIFICATIONS

Only the first part of this activity was performed during implementation. The second part of the lab, building a voltaic pile, failed to work during introduction period. Two classroom demonstrations were then added to the lab. The first demonstrations involved building an electrical circuit from salt water, aluminum foil, and copper to light an LED. This demonstration was later performed by students as part of the lab activity at Baan Muang Wittaya. The second demonstration required four C batteries and aluminum foil connected to an LED to show students how certain electrical components react when too much voltage is applied to them.

The science teacher at Baan E-Kud suggested handout questions to be qualitative, and relevant to students' lives. A safety questionnaire handout with hypothetical situations was then was added as part of this experiment (Appendix M).

BATTERY LAB FINDINGS

The following are findings drawn after completion of the implementation and assessment portion of the battery lab activity.

Students had difficulties answering questions that required written answers. During our initial student survey, we observed that students lacked confidence when asked to answer questions in the written form. We believe this affected students' reaction to the battery lab activity. The handout questions provided by our group proved to be too difficult for students (Appendix J), and from their exercise answers it became clear that many of them copied results from a classmate. We therefore concluded that students were not confident expressing their answers to written questions.

Materials used in the battery lab are not sustainable. Materials for the battery lab were not locally available at the project site. Lemons are not found locally, so limes were used instead. However, teachers reported during interviews (Appendix H) that limes are expensive when compared to local resources. They also commented that copper is hard to obtain. Teachers suggested that we try other citrus fruits such as Kaffir limes and other metals that are cheaper and more accessible.

OVERALL FINDINGS - LABORATORY ACTIVITIES

Throughout the implementation of the lab experiments, we found some problems to be common to all three activities. We also found that the labs seemed to improve student engagement overall. These findings were drawn from our assessment methods and observations of classroom activity.

The first finding common to all three activities was that **the lab activities took too much time to complete.** Teachers reported that they did not have enough time to adequately explain the concepts involved in each lab activity, and students communicated through focus groups that they felt rushed to complete the lab activities in a single class period. We also observed that many students lost interest in the lab activities after an hour to half an hour of work. From these findings, we concluded that the lab activities as originally designed were too long for use as part of a normal curriculum.

The second finding common to all three activities was that **students lacked confidence in their ability to answer written questions.** We found that students had a strong tendency to copy either textbooks or each other when asked to answer a question in writing; even when asked opinion questions on surveys, some students copied each other. We also found that student answers were short and lacked explanation, even when students were explicitly asked to provide explanations. This may have been due to the fact that many students did not speak Thai as a first language; however, it may also be due to a lack of experience with writing in general.

The third conclusion we drew about the lab activities regards active learning and student engagement. Based on our observations, **students were more engaged in learning while performing lab activities than during a normal class**. Although both normal classes and lab classes contained students who were not paying attention, more students appeared engaged while performing lab activities. This finding agreed with our research, which suggested that active learning results in increased student engagement (Bonwell et al., 1991; Bilgin 2006).

OVERALL FINDINGS – SITE SPECIFIC FINDINGS

Throughout the course of our project, we were able to draw conclusions about several general issues not specific to our lab activities. These issues were related to the conceptual basis of our project in science education. Although we did not perform any data collection with the intent to analyze these issues, several trends were discovered during our time in Sakon Nakhon that allowed us to draw general conclusions.

The first general issue which we considered was science literacy. In both the developing and developed world, the improvement of science literacy is a concern. However, in places like rural Thailand where science and technology do not dominate everyday life, science literacy takes on a slightly different meaning. **In developing areas, science literacy takes on a meaning of practicality, rather than generality**. Because few residents of the rural northeast are likely to need a theoretical or philosophical background in science, the more abstract aspects of science literacy take on less importance in areas such as Sakon Nakhon. Rather, a person from this area should be considered literate in science if he or she understands the importance of applying scientific knowledge to everyday decisions and dilemmas, and actively applies science concepts to understanding the world.

We found that this distinction was important because, while a general understanding of science may be abstractly important, a practical application of science and technology is much more valuable to a person living in a rural setting. Because very few of the students involved in our project were college-bound, it is unlikely that they will ever be required to design a scientific experiment or publish a paper. However, they may encounter a situation where application of scientific knowledge will save lives or prevent injury, such as a situation involving medical, chemical, or electrical safety. It is this practical application of science, rather than abstract concepts, that we believe science education should seek to improve in rural areas.

The second area we were able to analyze was teacher confidence in active learning. Although there were exceptions, we found that in general **teachers were confident using active learning methods.** Even during normal classroom observation, we observed most teachers using inquiry-based and constructive learning methods by asking students questions such as “what do you think will happen if…?” and relating the lesson to students’ conceptions of physical phenomena. Although not all of the teachers involved in our project were confident with active learning, the majority used active learning methods without hesitation. However, some of their comfort and confidence using active learning methods may have resulted from our help and support as well as our presence at the schools.

All of our analysis should be considered in light of possible bias introduced by our presence. Because our presence at the schools was an unusual occurrence, both students and teachers may have felt that they were being evaluated by us, or that they would be helping us by responding more positively. Therefore, their reactions to our surveys and interviews may not accurately reflect their true opinions. Also, our interactions in the classroom could have provided extra help that was not normally available, making it easier to perform the activities we planned. This may have contributed to more positive results than would be seen in a classroom using only the lab manual.

Although we have been careful to avoid it, our inexperience with research methods may have also contributed to a biasing effect inherent to our assessment, i.e. a bias due to leading questions and non-objective wording. Our assessment methods were developed specifically for this project and have not been validated experimentally, and they should not be considered scientifically rigorous. Similarly, because some of the labs used in this project were developed specifically for this project, they have not been rigorously tested and may appear to give positive results in student engagement without actually being educationally valuable.

CONCLUSION

From our experiences in Sakon Nakhon, we were able to draw several conclusions about our work. These conclusions range from general perspectives on science education to specific critiques of our lab activities. Based on these conclusions, we made several recommendations for our sponsor, the teacher supervisor of the Kusuman district, and potential future researchers. These recommendations are aimed toward our sponsor and are intended to advance science literacy through our labs.

SCIENCE LITERACY AND SCIENCE EDUCATION IN SAKON NAKHON

The region of Sakon Nakhon presents unique challenges for the improvement of science education. Because the theoretical aspects of science and technology are not often thought of as prevalent features of everyday life, science literacy and its improvement take on a different meaning in Sakon Nakhon. However, some methods of improving science education remain unchanged. For example, laboratory activities are just as useful for improving science education in rural Thailand as in more developed regions.

We found that **science literacy takes on a different meaning in undeveloped areas** such as Sakon Nakhon. Because many students in the region are not college-bound, they may never need to know the philosophical underpinnings of science. However, they probably will need to know how to apply science to situations they encounter in everyday life. In rural areas, science literacy takes on a meaning of practical application rather than general knowledge.

Over the course of our project, it became apparent that **improving science literacy was not an achievable short-term goal.** Because the effects of individual lab activities on science literacy are not measurable, it was not useful to consider science literacy as a deliverable goal for this project. Any impact our project might have on science literacy will take place over the long term, as science literacy measures an individual's fundamental perceptions of science. Because of our short time frame and difficulty in measurement, it was unreasonable to include the improvement of science literacy in the scope of this project. It was more reasonable to improve science education through student engagement in science.

We found through observation that **hands-on learning engaged students in science.** During observation of a normal class period, engagement in class was not high with many students not paying attention and talking among themselves. However, when observing classes in which hands-on learning methods such as lab activities were used, students were focused on their tasks and discussing them in groups. Also, in their surveys, students reported that they were very engaged in the lab activities while performing them and less engaged by less hands-on learning, such as answering questions.

ASSESSMENT OF THREE SCIENCE ACTIVITIES AT TWO SCHOOLS IN SAKON NAKHON

BIOTECHNOLOGY BOARD GAME

The biotechnology board game for Matthayom 1 was meant to help students learn about biotechnology farming concepts. In the game, students run a small farm and attempt to make as much money as possible using farming strategies. From our assessments and observations, this was **the most engaging and fun lab activity** to the students. The students appeared to enjoy the feeling of ownership and managing money. Teachers later reported that the lab was engaging and **educationally valuable**. The teachers also said that the lab was **relevant to students' lives** because Sakon Nakhon is mainly an agricultural economy.

The lab had a lot of educational potential, but we learned that it was **too complicated and took too long to learn** for the Matthayom levels. To successfully play the game students needed detailed and reinforced explanation of every rule. Because the game was complicated, students forgot rules and the educational value of the game was decreased. Therefore, we simplified the game and made the most complicated rules optional additions for teachers who want to introduce students to other farming concepts.

GROUNDWATER LAB

The groundwater lab for the Matthayom 2 level was designed to help students understand how contaminants flow through water and how to do pH testing. This lab had the **most successful implementation** of the three labs and required the least modification. Students appeared engaged throughout the lab activity, and teachers said that the lab was **educational and cost effective**.

Both students and teachers reported that the lab was **relevant to the lives of the people** in Sakon Nakhon. In post-lab surveys, students stated that they **learned about groundwater** in a fun environment with the lab and the majority of students said they would rather learn about science with labs rather than with textbooks and memorization. **Teachers at both schools said they would use this lab again**.

The groundwater lab did not need as much revision as the other two labs. Modifications included having the students gather materials from around the school so that teachers wouldn't have to and adding a filtration demonstration. We also specified a more exact amount of rocks, sand, and soil to use in the groundwater model as the results of the lab were dependent on these factors. Finally, we made the first and third parts optional to lower the time required for the lab based on data from teacher interviews and student focus groups.

BATTERY LAB

The battery lab was intended to help Matthayom 3 students understand electricity better. In this lab, students created batteries from organic materials and learned to analyze circuits. Students reported that this lab was **interesting** because they got to work with electricity for the first time. Students said they were surprised to learn that organic materials such as limes could be used to create voltage. The teachers reported that the lab was **simple and easy for the students to understand**, but recognized that **circuit analysis was difficult** for the students. They said they would **use the lab again if it was less expensive to implement**.

The battery lab had to go through significant revision before and after implementation. As the voltaic pile was difficult to successfully implement, it was removed from the lab. In its place, we added two optional demonstrations – one to demonstrate the voltaic pile concept and the other to show the dangers of excess voltage. We also added electrical safety questions that reflected real life situations to make the lab more relevant to the students' lives. However, the questions took a large part of the class period, and students seemed to lose interest in them quickly. As a result, we decided to make these questions optional.

PROBLEMS WITH ASSESSMENT

We concluded that there were some problems with our assessment process. First, **it was not feasible to gather information on whether these activities improved student learning directly.** Due to time constraints, we could not test student comprehension before and after lab activities or test a control group that learned the same concepts from a lecture. As a result, we cannot rigorously assess how much students actually learned from the labs or how educationally valuable they were.

Second, **we cannot be certain whether some of the engagement and excitement that we observed was not simply due to our presence.** For example, many students became excited when we entered a classroom. Students heard from friends about our activities and some classes even requested we do activities with them. Therefore, we cannot be sure whether they were excited about our labs or by our presence in their classrooms.

The last conclusion found regarding our assessment was that **students struggled to express themselves.** During surveys and focus groups, students were not always able to express their opinions effectively. When asked to respond in short-answer format on surveys, students either wrote extremely brief answers or copied from their peers. Similarly, in focus groups, students were hesitant to express themselves without encouragement, but once they began speaking, they were more expressive.

CRITERIA FOR SUCCESSFUL SCIENCE EXPERIMENTS IN SAKON NAKHON

Based on our work in Sakon Nakhon and our research, we comcluded that successful labs address 5 criteria. They should be relevant to students' lives, engaging, inexpensive, appropriate to the curriculum and ability level of the students, and brief. Of these criteria, our labs were originally developed to meet only the first four. However, we discovered over the course of our project that labs need to make effective use of time to maintain student interest.

From surveys, we found that **students were most interested by lab activities that are relevant to their lives.** Students reported that they were most interested by the lab activities when they directly related to their lives. We concluded that the two most interesting labs to the students were the groundwater lab and the biotechnology board game. Students reported that the second and fourth parts of the groundwater lab involving ground contamination and testing of local water were the most interesting and that they were also the most relevant to their lives. Similarly, in focus groups, some students reported that they were able to relate the board game to their lives since their families owned small farms.

Teachers made clear that **lab materials must be inexpensive and locally available** in order for the labs to be replicated. According to teachers, a major limiting factor in implementing labs is a lack of materials. Our project benefited from the budget provided to us by the Office of the Princess as well as being able to purchase materials in Bangkok, but under normal conditions schools do not have access to these resources. In order to avoid this problem, we have altered the materials lists for inclusion in the lab manual to contain more locally available materials at the expense of accuracy in lab results. For example, the battery lab has been altered to use copper wire and aluminum foil instead of copper and zinc strips.

When we began implementing the labs, we discovered that they were not part of the lesson plan students were studying at the time. Rather, **our labs were interjections into the normal lesson plan.** As a result, students did not have the background required for some of the labs, such as a background in electricity and electronic circuits for the battery lab. This made it difficult to judge how well the labs fit the curriculum and whether they were of an appropriate difficulty level.

Finally, we discovered that **labs should be concise and kept as short as possible**. All of our labs took an entire class period or longer to complete, preventing teachers from having sufficient time to explain the lab procedure and concepts. We also learned that science class periods had been doubled in length for the duration of our project. Under normal conditions, teachers would have struggled to complete our lab activities in time.

SUSTAINING AND DISSEMINATING SCIENCE LAB ACTIVITIES

After the development and implementation of the lab activities, the activities were disseminated to the rest of the Kusuman district. Based on the positive reactions of teachers involved in this project to the lab activities, we are hopeful that they will continue to use the lab activities in the future. Extending the impact of our project to teachers not directly involved was an objective of two dissemination strategies: an education fair held for teachers and students, and a lab manual for distribution to teachers.

When asked during interviews, all teachers involved in this project said the labs were educationally valuable and generally received them positively. Most teachers said that the labs were relevant to the students' lives and that they saw the students learning concepts faster than they would normally. All of the teachers told us that they would continue to use the labs in the future. However, it may be difficult for teachers to sustain these lab activities. Without the help of the project group, teachers will need to run the labs on their own and find time to do them. This will take extra effort preparing the labs and fitting them into their lesson plans accordingly.

Though these drawbacks may have a negative effect on the sustainability of the labs, we hope that the positive reactions of the teachers involved in this project are an indicator that the lab activities will be well-received by other teachers from the district.

Another indicator is the education fair, which was held on our last day in Kusuman to disseminate the project to about fifty teachers. The fair was meant to achieve two objectives – showing the teachers our lab activities and increasing student interest in science. We did not get direct feedback on what teachers thought of the labs or how students perceived the fair, but we concluded that the education fair was an overall success from the interaction with our teachers and students who ran the lab stations and our observations. The teachers from the district that came were able to see how well students had learned the labs as the students demonstrated them and how enthusiastic teachers from our schools were about them. This could be helpful in extending the use of the labs throughout the district as the district teachers saw the students engaged in the lab activities and spoke with teachers who understood the labs well.

Although the education fair served as an initial exposure to the labs for teachers, they did not receive enough information to implement the labs at their own schools from the fair alone. We made available the information needed to design new labs and implement the labs we designed in a lab manual. The suggestions and comments we gained during assessments with both teachers and students were used to develop the final copy of the lab manual. The manual was designed to be compact and user friendly. To further improve the accessibility of the manual, Chulalongkorn students translated the lab manual into Thai.

We are not sure if Kusuman district teachers will be able to adopt the lab activities or create their own using just this lab manual. Teachers may be unfamiliar with active learning methods, or may not have time to implement lab activities in their classrooms. However, if the Office of the Princess and the teacher supervisor recommend the use of the lab manual and support teachers' efforts, the lab manual should be successful.

RECOMMENDATIONS

Based on our project findings, we have several recommendations for researchers attempting a similar project. These recommendations range from practical concerns with lab implementation to suggestions for improving cultural exchange. We also have some recommendations intended for our project sponsors. These recommendations are intended to help maximize the effectiveness of our project and similar projects, and are drawn from our experiences during our time in Sakon Nakhon.

RECOMMENDATIONS FOR THE OFFICE OF THE PRINCESS

For the success of our project, **we recommend that the Office of the Princess distribute our lab manual throughout Kusuman district.** In conjunction with support from teacher supervisors, distribution of the lab manual will increase the impact of our project. However, the lab manual may need editing before distribution to be sure that translation is correct and materials available. We also recommend that the office encourage the use of these labs in the normal curriculum at the schools of Kusuman district and perhaps publish an article in a teaching magazine or teacher manual used in the district.

We recommend that the Office of the Princess continue to sponsor projects for the improvement of science literacy in Thailand. Our background research found that science literacy is important in the improvement of several societal issues such as poverty and public health. In addition, science literacy may improve environmental decision making. Because of the many benefits of science literacy, we recommend that further efforts to improve it be made.

RECOMMENDATIONS FOR THE TEACHER SUPERVISORS

We recommend that **schools incorporate more active learning methods.** The lab activities showed that active learning methods are effective in improving student interest and engagement in the science classroom. However, our review of the literature suggests that active learning is useful for improving student engagement in other subjects as well. Therefore we recommend that teacher supervisors promote active learning methods in classrooms of every subject.

As we found in our literature review, one method for encouraging teachers to use active learning methods is holding workshops where teachers perform active learning activities and discuss them among themselves. These active learning activities could include performing lab activities or demonstrating a lesson using active learning methods. In order to support the spread of active learning to other schools, we suggest that the teachers at our schools involved in this project lead such a workshop.

We recommend that, if possible, teacher supervisors **provide schools with additional teaching materials**. During our time in Kusuman we found that many students did not have access to a loaned textbook, and that the textbooks being used contained outdated or erroneous information. For example, one lesson on electricity contained inaccurate circuit diagrams. Because textbooks are an important part of the learning process, we believe that students should be provided with textbooks on loan if possible. We recommend that textbooks used by successful schools in Bangkok or Sakon Nakhon be considered as replacement textbooks.

We recommend that **general lesson plans be accessible to researchers in advance**. A general idea of what the teachers will be teaching each week would help researchers design labs that supplement rather than interject lessons. Teachers would not need to change their schedule and would already be teaching the background information relevant to the lab. Students would understand the lab material well before performing the lab. This would help them relate an abstract science concept to a relevant activity.

RECOMMENDATIONS FOR FUTURE PROJECT GROUPS

We recommend that lab developers **include visual aids and other teaching materials not dependent on language**. Because of the ethnic diversity of Sakon Nakhon and Kusuman district in particular, some students do not speak and read Thai fluently and therefore have difficulty understanding lab instructions in Thai. Visual aids would likely help these students understand concepts even though they may not understand the verbal explanations. Also, in cases where students don’t learn well from reading and listening, visual aids would help those students understand. We found that the battery lab in particular was difficult for students to understand without visual aids as electricity is abstract and cannot be seen. By contrast, during the groundwater lab, students were able to build their models based on the groundwater filtration demonstration and seemed to understand the flow of groundwater and contaminants well. Because visual aids improve student understanding and engagement, we recommend that labs incorporate them as much as possible.

Our second recommendation is that lab developers **keep labs concise and as short as possible**. Because students need to be given instructions and background for the lab activity, as well as an explanation after the activity, it is unreasonable to devote an entire class period to performing a lab. Teachers usually plan their lesson plans in advance and attempting to fit a long lab into their normal class time may prove to be the most challenging aspect of successfully implementing lab activities. We found that in classes where teachers did not spend sufficient time explaining the lab activity, students were confused and made mistakes. Furthermore, teachers felt that they did not have enough time to fully explain the concepts of a lab activity after it was completed. We recommend therefore that future projects design labs with the intention of fifteen minutes to a half hour of background and explanation, and a half hour to an hour of performing the lab.

Our third recommendation for future project groups is that **lab questions be developed cooperatively with the teachers.** Because the teachers are more familiar with the ability levels of the students their input is very useful when developing questions. For example, some of our questions were too difficult for students to answer because they were not familiar with the concepts involved. Also, teachers were sometimes unable to help students answer questions because they had not seen the questions prior to implementing the lab. In some cases, questions were not translated in simple enough language for students to understand, and teacher input would have been valuable in improving the translation. For these reasons we recommend that teachers be involved throughout the question design process.

We also recommend that future researchers **follow-up on the impact of this project.** Determining whether the lab activities are still in use at the two schools involved in this project will help researchers to decide how best to pursue their own project goal. If the lab activities are still being used, future researchers may decide to adopt some of our design criteria and implementation strategies. If they are not still in use, then future researchers can discover why not and address those problems in their own work. Researchers can also use information about our success disseminating the activities to design their own dissemination strategies.

CONCLUDING REMARKS

Active learning methods are a subject of debate and, although the adoption of active learning is a trend throughout the world, there is no consensus as to whether active learning methods improve student performance. However, we concluded from our research in Sakon Nakhon that there is an increase in student engagement and interest in science when active learning methods are used. Over the long term, it is our hope that this increase in student interest will help students to find ways to apply scientific concepts in their daily lives to make better decisions and interest them in furthering their education. These decisions are the true measure of science literacy. We would like to thank the office of H.R.H. Maha Chakri Sirindhorn for giving us this opportunity, and we hope that further efforts will be made to improve science literacy in rural Thailand.

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APPENDICES

APPENDIX A. THE ABBRIEVIATED THAI SECONDARY SCIENCE EDUCATION CURRICULA

The National Curricula on Science Education (3rd Level)

M1	M2	M3
The Plant Kingdom • Cells and cellular organs • Cell transport • Photosynthesis • Plant transport • Reproduction, crop propagation, crop improvement, and improve agricultural yield with biotechnology • Irritability in plant **Matters** • Classification of matters • Solution, acid-base • Chromatography and separation **Force and Movement** • Force and friction • Moment • Motions and movement in our daily life **Work and heat** • Work and energy • Heat and heat energy **Atmosphere** • The atmospheric composition • Air temperature, humidity, and barometric pressure • Weather and climate • Weather forecast and global climate	**Human Body** • Body systems • Growth and life quality • Food and nutrients • Drugs and the consequences of addiction **Animals** • Organells and their functions • Applications of biotechnology for animal breeding and genetic progress • Behavior **Change of matter** • Element and compounds • States of matters • Chemical reactions and their environmental consequences **Lights and images** • Light and light properties • Brightness and visual **Earth and earth changes** • Earth and the change of its crust • Soil, rocks, minerals • Surface and ground water	**Behavior and diversity of living things** • Heredity and evolution • Biotechnology application - genetic • Biodiversity **Life and the environment** • Local ecology • Population and natural resources **Electricity** • Introduction to electricity • Practical electricity **Electronics** • Introduction to electronics • Basic electricity circuits **Universe** • Celestial objects • Universe, galaxy, constellations • Space technology

APPENDIX B. THE OFFICE OF H.R.H PRINCESS MAHA CHAKRI SIRINDHORN'S PROJECTS' SUGGESTED LABORATORY TOPICS

Level	First Choice	Second Choice
M1	Applications of biotechnology in food production. Abundance of local produces are available during Jan-Feb	Chromatography and separation
M2	Chemical reactions and their environmental effects	Earth and earth changes
M3	Local ecology	Basic electronic circuits

APPENDIX C. INITIAL STUDENT SURVEYS FROM STUDENTS AT THE BAAN E-KUD AND BAAN MUANG WITTAYA SCHOOLS

Quantitative Section Instructions- On a scale of 1 to 5, answer the following questions

1.	How important is science to you?	Not at all <------> Very much 1 2 3 4 5
2.	How well do you feel you understand science?	Not at all <------> Very much 1 2 3 4 5
3.	How much do you want to learn more about science?	Not at all <------> Very much 1 2 3 4 5
4.	How much does science help you understand the world?	Not at all <------> Very much 1 2 3 4 5
5.	How interesting and engaging is science to you?	Not at all <------> Very much 1 2 3 4 5

Qualitative Section Instructions: Answer the following questions.

6. What is your favorite subject in school and why?
7. List some of the topics you have learned in science class.
8. Do you perform any lab activities in school? What labs, and how often?
9. What does science mean to you?
10. Do you like or dislike science? Why?

APPENDIX D. POST-LAB STUDENT SURVEY FORM

1. How engaging did you find this lab?	Not at all <------> Very much 1 2 3 4 5
2. How easy to understand was this lab?	Not at all <------> Very much 1 2 3 4 5
3. How much relevant to your life was this lab activity?	Not at all <------> Very much 1 2 3 4 5
4. How much did this lab interest you in science?	Not at all <------> Very much 1 2 3 4 5
5. Did you have enough time to complete this lab?	Not at all <------> Very much 1 2 3 4 5

Qualitative Section Instructions: Answer the following questions.

1. What was the most important thing you learned from this lab?
2. What was your favorite part of this activity, and least favorite? Why?
3. What would make this lab activity better?
4. Would you recommend this experiment to a friend?
5. Was this experiment challenging?

APPENDIX E. POST-LAB TEACHER INTERVIEW QUESTIONS

- What did you think of this lab activity?
- Do you think this lab will be educational for the students? Why or why not?
- Do you think this lab will be engaging for the students? Why or why not?
- Does this lab fit in with your curriculum? Why or why not?
- Were there areas that needed improvement?
- How can we improve them?
- Was anything unclear in the lab instructions? Why?
- Should anything be re-worded?
- Any other comments or concerns?

APPENDIX F. POST-LAB STUDENT FOCUS GROUP QUESTIONS

- Which was your favorite lab, and why?
- How is science important to you in your daily lives?
- What science topics do you want to learn more about, and why?
- Which lab did you learn the most from?
- Do hands-on activities like the labs help you learn? Why or why not?
- Comments?

APPENDIX G. INITIAL STUDENT SURVEY RESULTS

Initial Student Surveys were performed during our first week of field work. Preliminary Survey Questions were formulated (Appendix C). Results are displayed by Matthayom level.

Matthayom 1

Question 1 – How important is science to you? (1 to 5)

Total Responses: 61

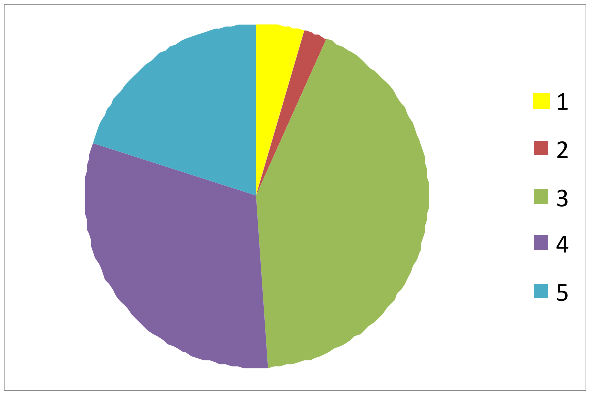
"1" responses: 2 (4.44%)

"2" responses: 1 (2.22%)

"3" responses: 19 (42.22%)

"4" responses: 14 (31.11%)

"5" responses: 9 (20.00%)



Initial Student Survey Chart 1 - Matthayom 1 Question 1

Question 2 – How well do you feel you understand science? (1 to 5)

Total Responses: 61

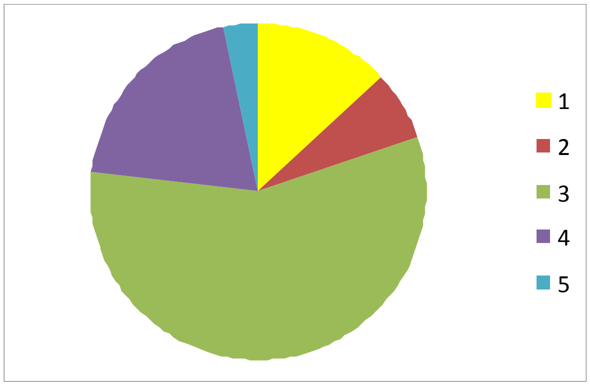
"1" responses: 8 (13.11%)

"2" responses: 4 (6.56%)

"3" responses: 35 (57.38%)

"4" responses: 12 (19.67%)

"5" responses: 2 (3.28%)



Initial Student Survey Chart 2 - Matthayom 1 Question 2

Question 3 – How much do you want to learn about science? (1 to 5)

Total Responses: 61

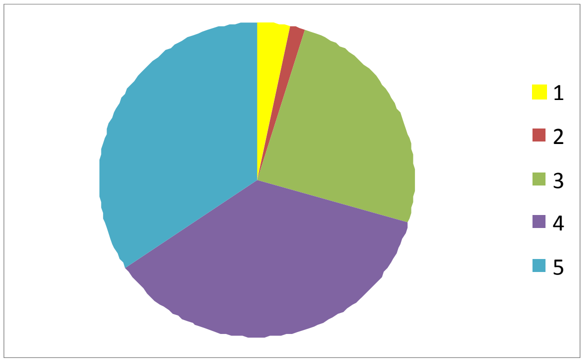
"1" responses: 2 (3.28%)

“2” responses: 1 (1.64%)

“3” responses: 15 (24.59%)

“4” responses: 22 (36.07%)

“5” responses: 21 (34.43%)



Initial Student Survey Chart 3 - Matthayom 1 Question 3

Question 4 - How much does science help you understand the world?

Total Responses: 61

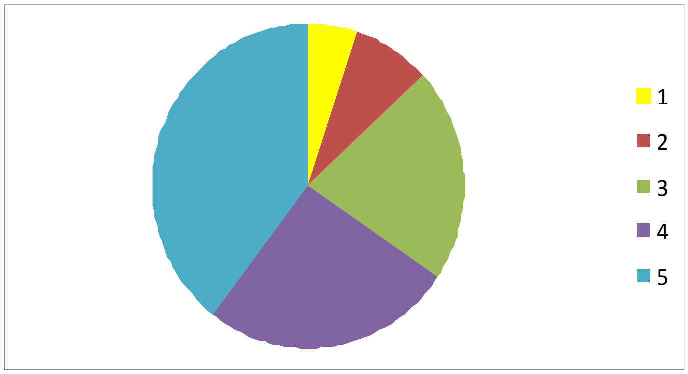
“1” responses: 3 (4.92%)

“2” responses: 5 (8.20%)

“3” responses: 13 (21.31%)

“4” responses: 16 (26.23%)

“5” responses: 24 (39.34%)



Initial Student Survey Chart 4 - Matthayom 1 Question 4

Question 5 - How interesting and engaging is science to you?

Total Responses: 61

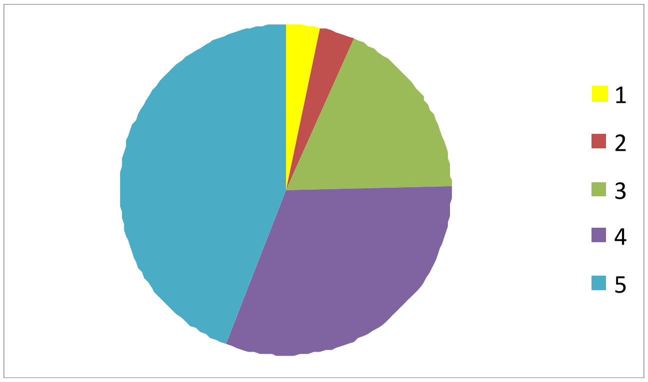
“1” responses: 2 (3.28%)

“2” responses: 2 (3.28%)

“3” responses: 11 (18.03%)

“4” responses: 19 (31.15%)

“5” responses: 27 (44.26%)



Initial Student Survey Chart 5 - Matthayom 1 Question 5

Qualitative Conclusions from Matthayom 1

- Only nine of the fifty-nine students surveyed in Matthayom 1 listed science as their favorite subject.
- At Baan Muang Wittaya, labs were performed at least once a week, but at Baan E-Kud, they were only performed about once a year.
- Most students said they liked science, citing that they get to perform experiments or that it's fun.
- Students who didn't like science said they didn't because it was too hard or they didn't understand.

<u>Matthayom 2</u>

Question 1 – How important is science to you? (1 to 5)

Total Responses: 48

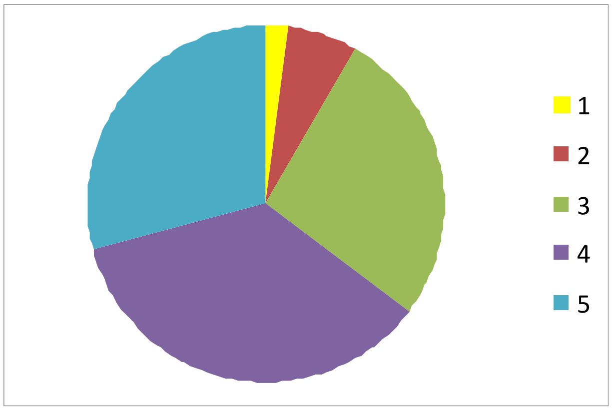
"1" responses: 1 (2.08%)

"2" responses: 3 (6.25%)

"3" responses: 13 (27.08%)

"4" responses: 17 (35.42%)

"5" responses: 14 (29.17%)



Initial Student Survey Chart 6 - Matthayom 2 Question 1

Question 2 – How well do you feel you understand science? (1 to 5)

Total Responses: 48

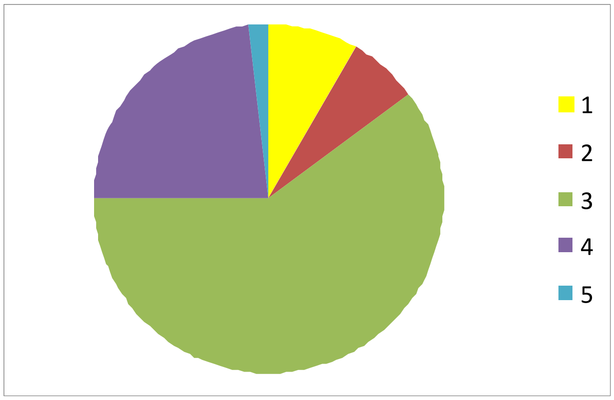
"1" responses: 4 (8.33%)

"2" responses: 3 (6.25%)

"3" responses: 29 (60.42%)

"4" responses: 11 (22.92%)

"5" responses: 1 (2.08%)



Initial Student Survey Chart 7 - Matthayom 2 Question 2

Question 3 – How much do you want to learn about science? (1 to 5)

Total Responses: 48

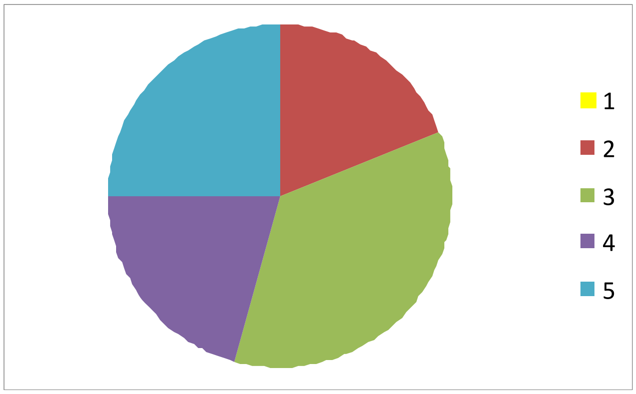
“1” responses: 0 (0%)

“2” responses: 9 (18.75%)

“3” responses: 17 (35.42%)

“4” responses: 10 (20.83%)

“5” responses: 12 (25.00%)



Initial Student Survey Chart 8 - Matthayom 2 Question 3

Question 4 - How much does science help you understand the world?

Total Responses: 45

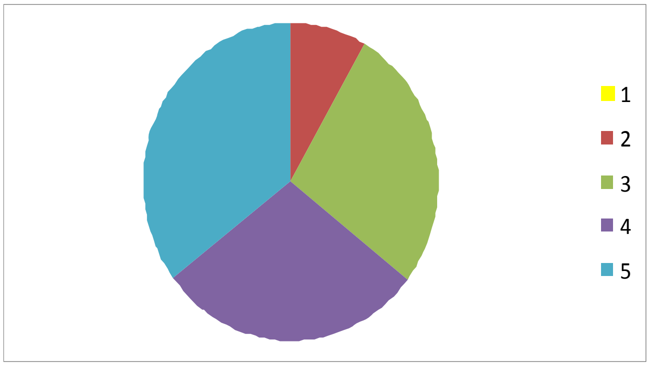
“1” responses: 0 (0%)

“2” responses: 4 (8.33%)

“3” responses: 13 (27.08%)

“4” responses: 14 (29.17%)

“5” responses: 17 (35.42%)



Initial Student Survey Chart 9 - Matthayom 2 Question 4

Question 5 - How interesting and engaging is science to you?

Total Responses: 45

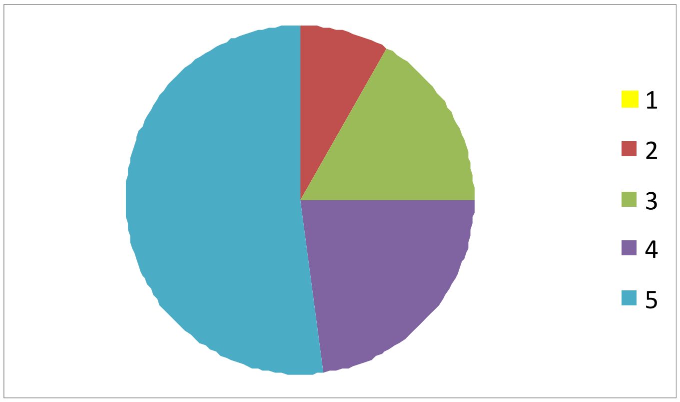
“1” responses: 0 (0%)

“2” responses: 4 (8.33%)

“3” responses: 8 (16.67%)

“4” responses: 11 (22.92%)

“5” responses: 25 (52.08%)



Initial Student Survey Chart 10 - Matthayom 2 Question 5

Qualitative Conclusions from Matthayom 2

- Only six of the forty-five students surveyed in Matthayom 2 listed science as their favorite subject.
- At Baan Muang Wittaya, labs were performed at least once a week. At Baan E-kud, labs were performed once or twice a month.
- All but one student said they liked science. The student who disliked science said he disliked science because not enough experiments were done.
- When asked what science meant to them, many students said experiments or research. Some said it helped them learn about the world around them or that they could use science in their daily lives.

Matthayom 3

Question 1 – How important is science to you? (1 to 5)

Total Responses: 21

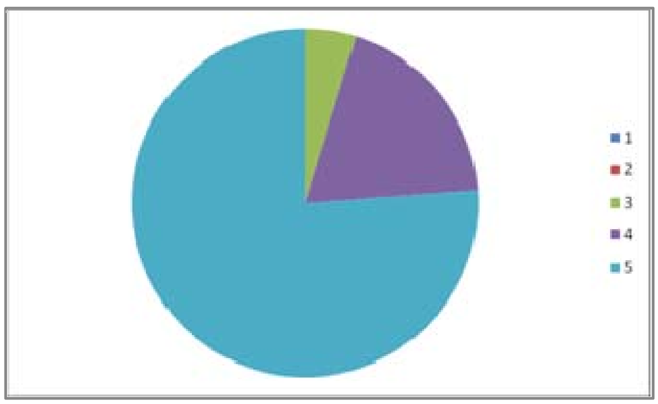
"1" responses: 0 (0.0%)

"2" responses: 0 (0.0%)

"3" responses: 1 (4.76%)

"4" responses: 4 (19.05%)

"5" responses: 16 (76.19%)



Initial Student Survey Chart 11 - Matthayom 3 Question 1

Question 2 – How well do you feel you understand science? (1 to 5)

Total Responses: 21

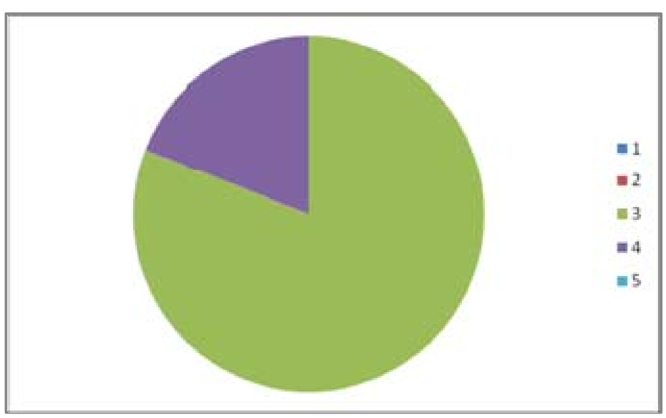
"1" responses: 0 (0.0%)

"2" responses: 0 (0.0%)

"3" responses: 17 (80.95%)

"4" responses: 4 (19.05%)

"5" responses: 0 (0.0%)



Initial Student Survey Chart 12 - Matthayom 3 Question 2

Question 3 – How much do you want to learn about science? (1 to 5)

Total Responses: 21

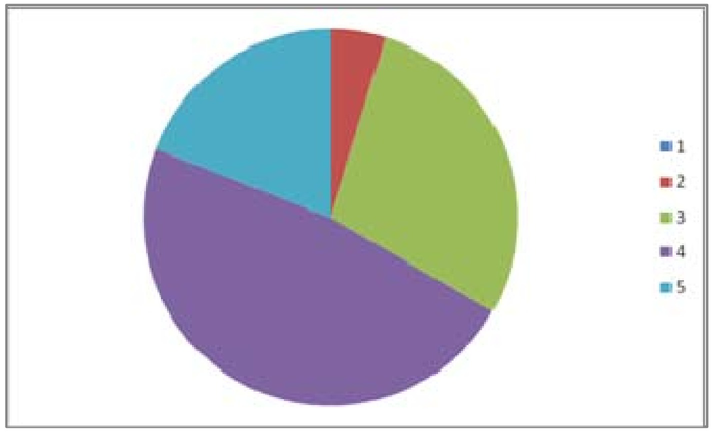
"1" responses: 0 (0.0%)

"2" responses: 1 (4.76%)

"3" responses: 6 (28.57%)

"4" responses: 10 (47.63%)

"5" responses: 4 (19.05%)



Initial Student Survey Chart 13 - Matthayom 3 Question 3

Question 4 - How much does science help you understand the world?

Total Responses: 21

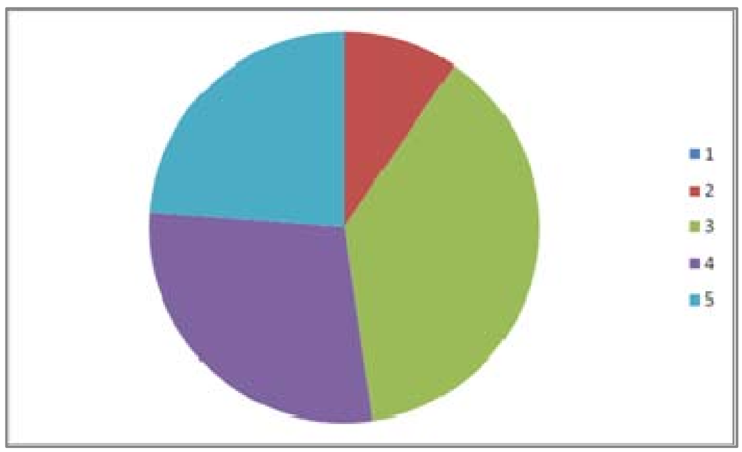
"1" responses: 0 (0%)

"2" responses: 2 (9.52%)

"3" responses: 8 (38.09%)

"4" responses: 6 (28.57%)

"5" responses: 5 (23.81%)



Initial Student Survey Chart 14 - Matthayom 3 Question 4

Question 5 - How interesting and engaging is science to you?

Total Responses: 21

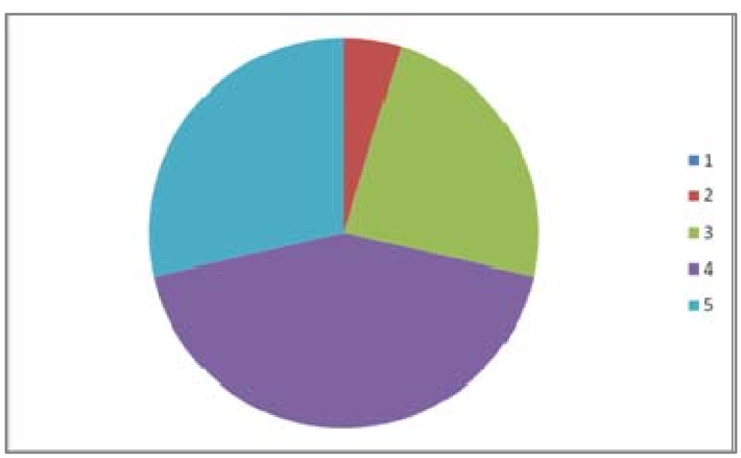
"1" responses: 0 (0%)

"2" responses: 1 (4.76%)

"3" responses: 5 (23.81%)

"4" responses: 9 (42.86%)

"5" responses: 6 (28.57%)



Initial Student Survey Chart 15 - Matthayom 3 Question 5

Qualitative Conclusions from Matthayom 3

- Of the twenty-one students surveyed in Matthayom 3, two said science was their favorite subject, citing experiments as their reason.
- Students at Baan E-Kud did labs one to three times per month, mostly biology labs.
- All students said they liked science.

APPENDIX H. POST-LAB TEACHER INTERVIEW RESULTS

Science teachers were interviewed 2 or 3 days after implementation of lab activity. Preliminary questions were formulated (Appendix E). Results are divided by Matthayom level.

MATTHAYOM 1 –BIOTECHNOLOGY BOARDGAME

BAAN E-KUD M1 SCIENCE TEACHER INTERVIEW: A. KAJORNSAK, JANUARY 27TH, 2009

Q1: Was Did you feel confident and comfortable teaching the lab activities? Why or why not?
A: *Yes, I was happy. The lab was relevant to students' lives; it made them think about their families.*

Q2: What were the weaknesses of the lab activities, and areas that could be improved?
A: *I think the cost of some items could change. We could make certain items more expensive, because in the game no one went bankrupt—which isn't realistic. Also, students wanted to play at the same time, creating chaos. It was a good game, but it had a lot of details. Students would understand concepts better if more time was given though.*

Q3: Does this lab fit with the curriculum at your school?
A: *I think so, but I am not their science teacher.*

Q4: Was this lab activity suitable for a Matthayom 1 classroom?
A: *Yes, students seemed to understand the lab. I would also like to teach the game to Prathomsuksa 6, Matthayom 2, and Matthayom 3.*

Q5: Do you think you will use lab activities in your classroom in the future? Why or why not?
A: *Yes, the game will be used in the future. It serves as a good medium to convey important concepts to students.*

BAAN MUANG WITTAYA M1 SCIENCE TEACHER INTERVIEW: A. LUKANA, FEBRUARY 11TH, 2009

Q1: What were the strengths and weaknesses of this lab?

A: *Strengths: The game gave students a good comparison to real life situations. Students got to observe real life effects that would take over ten years to happen in a one hour class period. They got to think and analyze how they can increase the efficiency of their crop yield and at the same time consider environmental effects. Students also learn how to be honest with themselves, being that they are dealing with their own money.*

Weaknesses: There were too many rules to the game. But I'm positive that students can learn all of them given enough time. Some students are impatient and can't always concentrate for so long, while instructions are given. Also, I was the only teacher in the classroom, making it hard to go around and give every group the necessary instructions.

Q2: Does this lab fit with the curriculum at your school?

A: *Yes. Students learn about certain chemicals in their class, and also about the environment.*

Q3: How can the weak areas of this lab be improved?

A: *In order for all the students to get the most out of the game, I think it's important that they all understand the rules. It would be practical to teach a small group of students the rules first and then have them help their classmates after. The time of the game is ok as long as students get to play more than once to get used to the rules. Parts don't need to be cut out, it is important to stick to what is realistic. Materials and cards should be more durable, though.*

Q4: Do you think you will use lab activities in your classroom in the future? Why or why not?

A: *Yes, this lab will be used in the future. It can be used for all M1-M3 levels.*

MATTHAYOM 2 –GROUNDWATER LAB

BAAN E-KUD M2 SCIENCE TEACHER INTERVIEW: A. RATCHDAPORN, FEBRUARY 10TH, 2009

Q1: Was the lab activity helpful in your classroom? Why or Why Not?

A: *Yes, lab activity was very useful to students because it allowed them to understand their surroundings.*

Q2: What were the strengths of the lab activities? Which parts worked the best?

A: *The biggest strength of this lab was that it related to the students' lives. It used natural materials that were easy to find around the school.*

Q3: What were the weaknesses of the lab activities, and areas that could be improved?

A: *It would be a good idea to let students bring water from their own homes for pH testing, one sample per person. It can be from anywhere they want, that way it will build up their interest. One student even asked to bring pH paper to test water at home. The pH paper experiment (Part III) could also be cut down because students already have background from class. This experiment simply verifies what they have already learned in theory. Glass straw could also be used instead of plastic straw, since plastic straws broke easily. Part II of the lab is most fun and at the same time most time consuming. Experiment should focus mainly on this part. Students can also prepare materials for the lab before class starts, that way it won't lose time in class.*

Q4: Did you feel confident and comfortable teaching the lab activities? Why or why not?

A: *I enjoyed teaching the lab but most of the explanation I provided in class was not a science teacher's perspective (I'm not a science teacher). So, sometimes I feel like I cannot convey knowledge to students as effective or the way a professional science teacher does.*

Q5: Do you think you will use lab activities in your classroom in the future? Why or why not?

A: *It's a very good lab and definitely teaches students important concepts. Some modifications need to be made in order to suit students' interest.*

Q6: Was this lab activity suitable for a Matthayom 2 classroom?

A: *Yes, this lab for suitable for their level, even though science education in rural areas tend to fall behind.*

Q7: What do you believe is the educational value of this experiment?

A: *Students understand what's going on during the experiments, but they cannot explain it in theory the concepts behind their actions. Hand-out questions don't need to be changed, but teachers should be the ones providing them to students. It needs to better fit the background prior to performing the experiment.*

BAAN MUANG WITTAYA M2 SCIENCE TEACHER INTERVIEW: A. LUKANA, FEBRUARY 10TH, 2009

Q1: What were the strengths and weaknesses of this lab?

A: *Strengths: for Part I, students got to compare which substances can clear water better. For Part II, they got to imagine the different layers of groundwater. It was a very good model. They also observed groundwater flow even when contaminants flow through. Students learned about how this system is relevant to their lives.*

Weaknesses: Soil, for Part I, is not easily available. We had to buy it from another source. Part III became unclear because it did not become clear to students how the substances they use can affect the pH of water when they are mixed together. There was not enough time.

Q2: Does this lab fit with the curriculum at your school?

A: *Yes.*

Q3: How can the weak areas of this lab be improved?

A: *There wasn't enough time, as it took too long to do all the parts. They should be separated. The parts weren't necessarily connected to each other—there could have been more connections, but it would require more time for explanation as well.*

Q4: Do you think you will use lab activities in your classroom in the future? Why or why not?

A: *Yes, this lab will be used in the future.*

MATTHAYOM 3 –BUILD A BATTERY LAB

BAAN E-KUD M2 SCIENCE TEACHER INTERVIEW: A. NIPPON, FEBRUARY 10TH, 2009

Q1: Was the lab activity helpful in your classroom? Why or Why Not?

A: *Yes, students can apply this knowledge in their lives. For example, going into a career in electronics.*

Q2: What were the strengths of the lab activities? Which parts worked the best?

A: *By performing labs, students can understand concepts better than listening to lectures. The activity was also helpful because students can apply the formulas they learned in careers. They also seemed excited to create electric current from natural materials*

Q3: Was there enough time to perform this lab in your classroom?

A: *Yes The battery part wasn't very time consuming. It was enough for one class, because if the demonstrations were to be performed by the students (salt water and LED burn demonstration) they would not have time to finish.*

Q4: Did the lab material fit with the M3 curriculum?

A: *It fit. Most students should have background in electricity already—students learned about it during Matthayom 1 but had already forgotten it.*

Q5: Do you think you will use lab activities in your classroom in the future? Why or why not?

A: *Yea. Most equipment used in the lab is easy to find, and appropriate for the classroom. I'm not the science teacher, but if still get to teach this class I will implement this lab. Maybe using other types of metals instead of zinc and copper. We also have our own voltmeter, just not a digital one.*

Q6: How can we improve the weak areas of this lab?
A: *I think the teacher should have his own set of lab equipment at the beginning of class for demonstration. Also, the handout questions were too few. They were simple 'plug into equation' questions—questions could be more worded, giving the students hypothetical situations that they can relate to their real lives. For example "you are planning on buying a light bulb with X resistance…"*

BAAN MUANG WITTAYA M2 SCIENCE TEACHER INTERVIEW: A. LUKANA, FEBRUARY 13TH, 2009

Q1: What were the strengths and weaknesses of this lab?
A: *Strengths: Students had learned about battery/electricity but had only done so in theory. They don't usually get to perform labs, it was a very good opportunity. The lab was simple and easy to understand and various materials were used. The topic from this lab was very objective, not too subjective—relating to what they have already learned in theory.*
Weaknesses: Safety should be enhanced. Some parts are dangerous (burning the LED, touching both ends of the battery). About availability of materials, if copper strip isn't available, copper wire can be used.

Q2: Does this lab fit with the curriculum at your school?
A: *It does. Students seem engaged and pro-active.*

Q3: How can we improve the weak areas of this lab?
A: *More time could be given for students to answer questions. There is enough time to do lab but not enough time to explain exercise questions and conclusions to the class.*

Q4: Do you think you will use lab activities in your classroom in the future? Why or why not?
A: *Yes, this lab will be used in the future. It is easy to prepare and simple. Plus, concepts are easy to understand.*

APPENDIX I. POST-LAB STUDENT SURVEY RESULTS

Post-lab Student Surveys were performed during after each lab during field work. Post-lab Survey Questions were formulated (Appendix D). Results are displayed by Matthayom level.

<u>Matthayom 1</u>

Question 1 – How engaging did you find this lab? (1 to 5)

Total Responses: 63

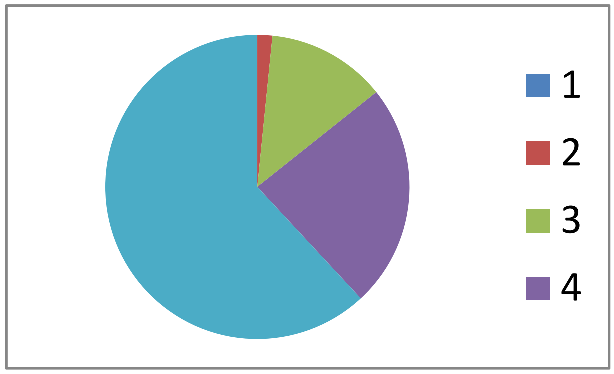
"1" responses: 0 (0.00%)

"2" responses: 1 (1.59%)

"3" responses: 8 (12.70%)

"4" responses: 15 (23.81%)

"5" responses: 39 (61.90%)



Post-Lab Student Survey Chart 1 - Results for Matthayom 1 Question 1

Question 2 – How easy was this lab to understand? (1 to 5)

Total Responses: 63

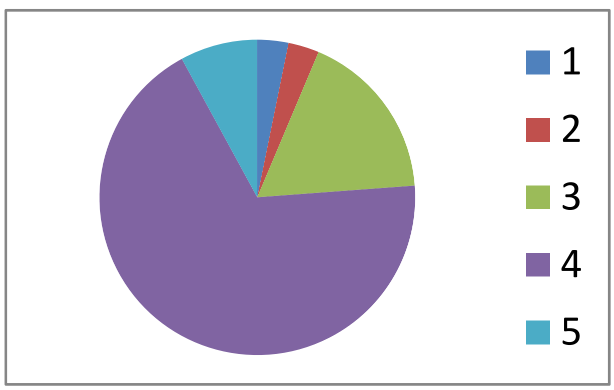
"1" responses: 2 (3.17%)

"2" responses: 2 (3.17%)

"3" responses: 11 (17.46%)

"4" responses: 43 (68.25%)

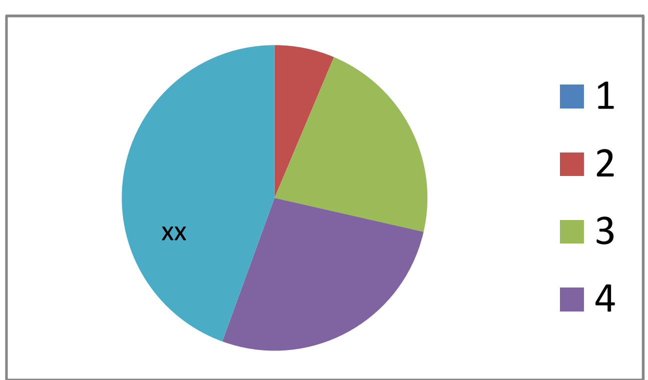
"5" responses: 5 (7.94%)



Post-Lab Student Survey Chart 2 - Results for Matthayom 1 Question 2

Question 3 – How relevant to your life was this lab? (1 to 5)

Total Responses: 63



“1” responses: 0 (0.00%)

“2” responses: 4 (6.35%)

“3” responses: 14 (22.22%)

“4” responses: 17 (26.98%)

“5” responses: 28 (44.44%)

Post-Lab Student Survey Chart 3 - Results for Matthayom 1 Question 3

Question 4 - How much did this lab interest you in science?

Total Responses: 63

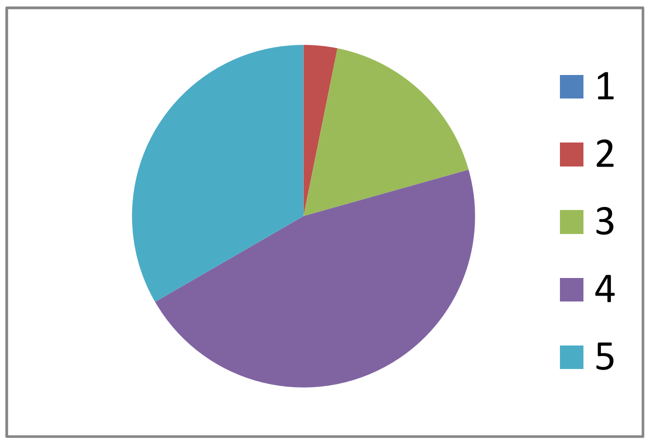
“1” responses: 0 (0.00%)

“2” responses: 2 (3.17%)

“3” responses: 11 (17.46%)

“4” responses: 29 (46.03%)

“5” responses: 21 (33.33%)



Post-Lab Student Survey Chart 4- Results for Matthayom 1 Question 4

Question 5 – Did you have enough time to complete this lab?

Total Responses: 63

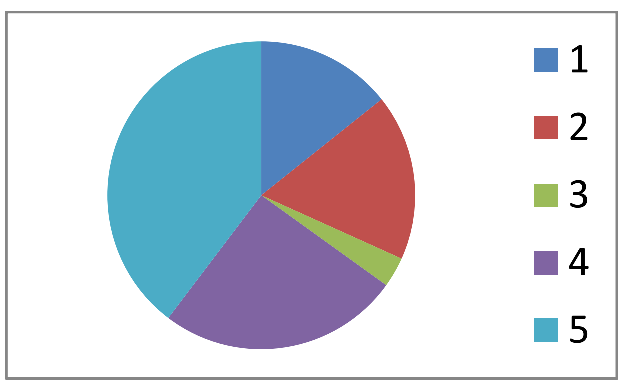
“1” responses: 9 (14.29%)

“2” responses: 11 (17.46%)

“3” responses: 2 (3.17%)

“4” responses: 16 (25.40%)

“5” responses: 25 (39.68%)



Post-Lab Student Survey Chart 5- Results for Matthayom 1 Question 5

<u>**Matthayom 2**</u>

Question 1 – How engaging did you find this lab? (1 to 5)

Total Responses: 44

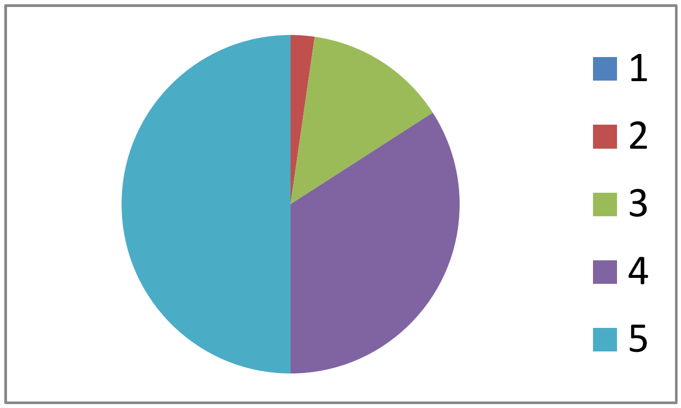
“1” responses: 0 (0.00%)

“2” responses: 1 (2.27%)

“3” responses: 6 (13.64%)

“4” responses: 15 (34.09%)

“5” responses: 22 (50.00%)



Post-Lab Student Survey Chart 6 - Results for Matthayom 2 Question 1

Question 2 – How easy was this lab to understand? (1 to 5)

Total Responses: 44

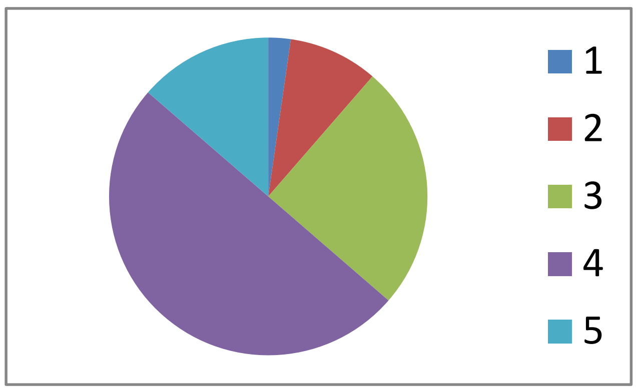
“1” responses: 1 (2.27%)

“2” responses: 4 (9.09%)

“3” responses: 11 (25.00%)

“4” responses: 22 (50.00%)

“5” responses: 6 (13.64%)



Post-Lab Student Survey Chart 7 - Results for Matthayom 2 Question 2

Question 3 – How relevant to your life was this lab? (1 to 5)

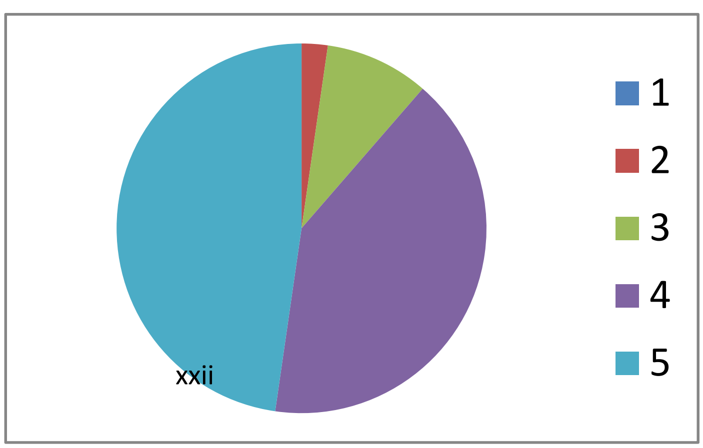
Total Responses: 44

“1” responses: 0 (0.00%)

“2” responses: 1 (2.27%)

“3” responses: 4 (9.09%)

“4” responses: 18 (40.91%)



“5” responses: 21 (47.73%)

Post-Lab Student Survey Chart 8 - Results for Matthayom 2 Question 3

Question 4 - How much did this lab interest you in science?

Total Responses: 44

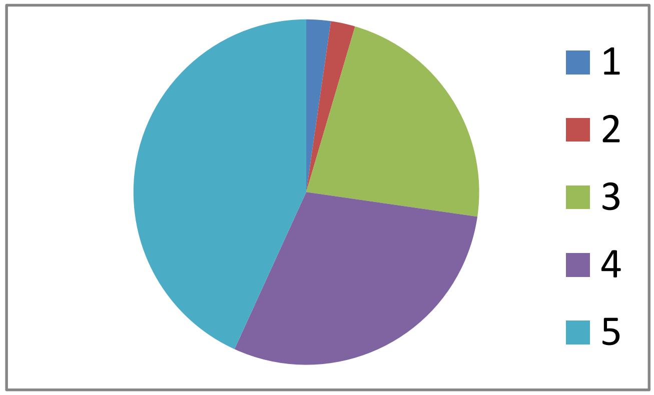
“1” responses: 1 (2.27%)

“2” responses: 1 (2.27%)

“3” responses: 10 (22.73%)

“4” responses: 13 (29.55%)

“5” responses: 19 (43.18%)



Post-Lab Student Survey Chart 9 - Results for Matthayom 2 Question 4

Question 5 – Did you have enough time to complete this lab?

Total Responses: 44

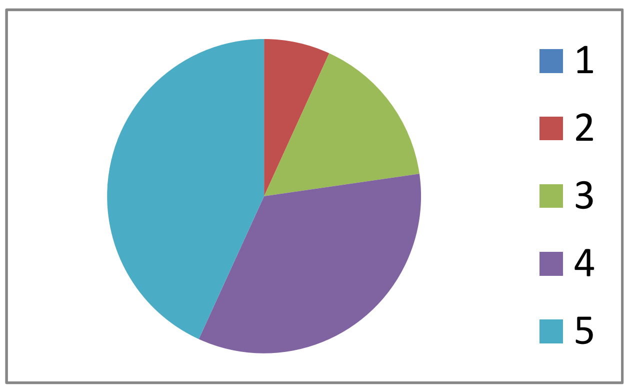
“1” responses: 0 (0.00%)

“2” responses: 3 (6.82%)

“3” responses: 7 (15.91%)

“4” responses: 15 (34.09%)

“5” responses: 19 (43.18%)



Post-Lab Student Survey Chart 10 - Results for Matthayom 2 Question 5

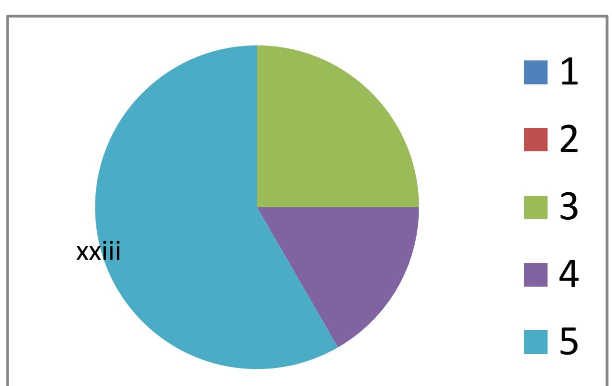
<u>Matthayom 3</u>

Question 1 – How engaging did you find this lab? (1 to 5)

Total Responses: 24

“1” responses: 0 (0.00%)

“2” responses: 0 (0.00%)



“3” responses: 6 (25.00%)

“4” responses: 4 (16.67%)

“5” responses: 14 (58.33%)

Post-Lab Student Survey Chart 11 - Results for Matthayom 3 Question 1

Question 2 – How easy was this lab to understand? (1 to 5)

Total Responses: 24

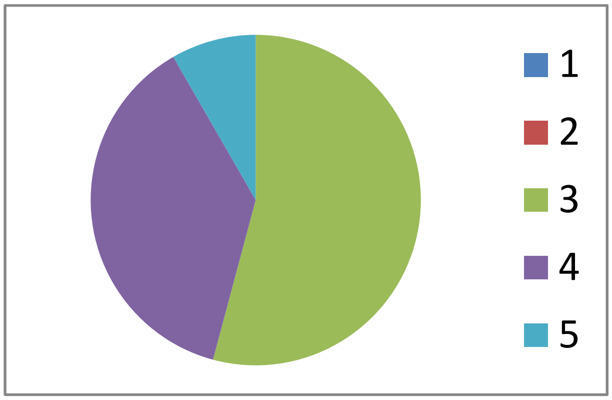
“1” responses: 0 (0.00%)

“2” responses: 0 (0.00%)

“3” responses: 13 (54.17%)

“4” responses: 9 (37.50%)

“5” responses: 2 (8.33%)



Post-Lab Student Survey Chart 12 - Results for Matthayom 3 Question 2

Question 3 – How relevant to your life was this lab? (1 to 5)

Total Responses: 24

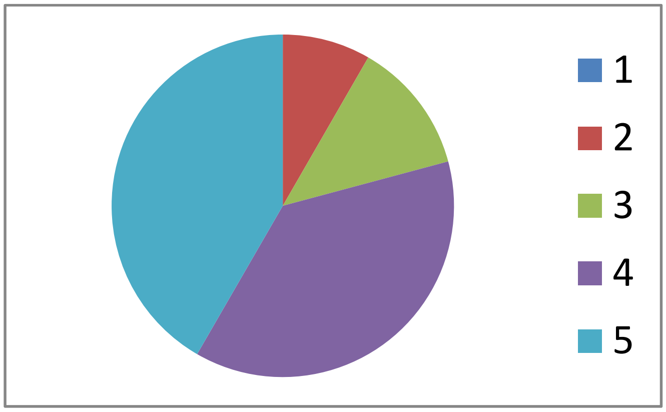
“1” responses: 0 (0.00%)

“2” responses: 2 (8.33%)

“3” responses: 3 (12.50%)

“4” responses: 9 (37.50%)

“5” responses: 10 (41.67%)



Post-Lab Student Survey Chart 13 - Results for Matthayom 3 Question 3

Question 4 - How much did this lab interest you in science?

Total Responses: 24

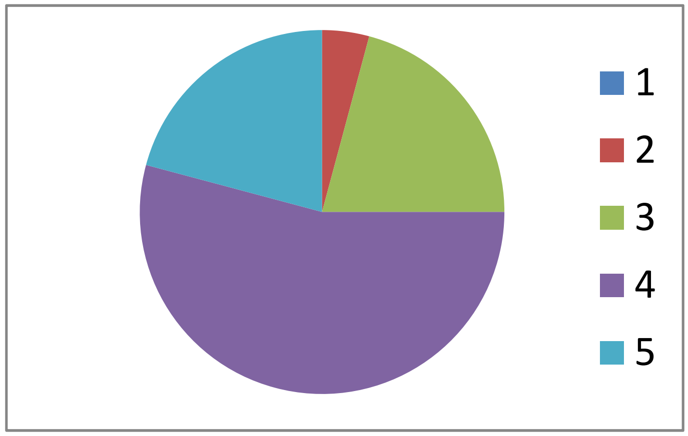
“1” responses: 0 (0.00%)

“2” responses: 1 (4.17%)

“3” responses: 5 (20.83%)

“4” responses: 13 (54.17%)

“5” responses: 5 (20.83%)



Post-Lab Student Survey Chart 14 - Results for Matthayom 3 Question 4

Question 5 – Did you have enough time to complete this lab?

All students finished the lab within class time so this question was not asked.

APPENDIX J. POST-LAB STUDENT FOCUS GROUPS

Post-lab focus groups were performed in groups of 5-8 students. Though preliminary questions were formulated (Appendix XX), most discussion was done without a particular format. Results are divided by Matthayom level.

MATTHAYOM 1 –BIOTECHNOLOGY BOARD GAME

Baan E-Kud School 6 students: February 10th, 2009

- Lab activity was not too difficult, and it was fun
- Soil depletion rule was confusing, chemical fertilizer rule was harsh
- Good for learning concepts of chemical vs. organic fertilizers
- Students don't like science because they don't get to do experiments that often
- Greenhouse rule was not really necessary
- Normally don't feel that science is important to their lives, but know that it is related to what they do for living
- Parents of students are farmers: grow chili
- Only one student will continue studying after Matthayom 3 (9th grade)
- Five out of six students think experiments help them learn better
- Visual aids are helpful in understanding scientific concepts
- One student said he has learned about microscopes before, and really wishes to use one
- Students don't think what they learn in science class is enough

Baan Muang Wittaya

- Students have a hard time expressing themselves freely, seem intimidated
- Students enjoyed the game and 'nothing should change about the game'
- Game helps them understand concepts, they want more experiments
- Game can be applied to their lives and agriculture
- It was fun investing money, especially with fertilizers
- Game can be played even without all concepts are understood
- Game is fun, but doesn't particularly make them like science more
- Science class should be more about doing experiments
- The whole game should be translated, as opposed to a few parts

- Would like to use utensils such as Bunsen burners, or scale
- Students seem excited when told about the Education Fair
- Most students wish they could continue with their education after Matthayom 3

MATTHAYOM 2 –GROUNDWATER LAB

Baan E-Kud School, 6 students: February 10th, 2009

- Students speak in So language amongst themselves during discussion
- Favorite part of the lab was part II (3 students), followed by part I (2 students), then part IV (one student). Students thought part III was confusing
- Wish to test pH water from other sources
- Barely conduct experiments. Class usually consists of summarizing the book and answering end of the chapter questions
- Science is important because it is relevant to their lives
- Many students already forget the lab topics after 2 days and need to be reminded
- Students wish our group could stay longer. Many asked if we are going to introduced more labs

Baan Muang Wittaya, 6 students: February 11th, 2009

- Boys seemed to stay quiet. Only talked when spoken to. Spoke Isaan/Laos with each other
- Experiment was fun, learned how to work in teams better. It was challenging
- Experiment could be more difficult, students felt they understood the whole lab
- Part II, favorite part: learned more about groundwater flow and contaminants underground
- Have only performed a few experiments, it is not done often
- Students believe their knowledge of experiment can be used in daily lives
- 3 students like science, 3 don't
- Some students claim science isn't really related to their lives, while some think scientific knowledge can improve their lives. They argue.
- Students believe they learn most from doing experiments

MATTHAYOM 3 –BATTERY LAB

Baan E-Kud School: February 12th, 2009

- It was difficult to understand explanation during lab activity from foreign students
- Lab was fun, but should be longer
- Students want to burn out LED and do the demonstration sections of the lab on their own
- Handout questions weren't too difficult—learned the concepts in Matthayom 1
- Could use more limes, and test out different types of metals for the experiment
- During class, students mostly learn by reading, taking notes, and answering questions
- Afraid to answer handout experiments wrong
- Science is boring when don't get to do experiments

Baan Muang Wittaya

- Students enjoyed burning up the LEDs
- Some have already built up a water filtration system for their houses
- Claim they understand the importance of science in their outside life
- Only one student in the group does not enjoy experiments
- Formula part of the handout was too hard, seems for adults
- Asking if foreign students want to come back
- Most girls want to continue with their education
- Students say there is not enough material for science class
- Trust and like science teacher at the school

APPENDIX K. CULTURAL LEARNING IN THAILAND

The WPI-Bangkok Project Center provides students with a special opportunity to advance their intercultural awareness and competence. During the preparation period and on-site, students learn about general categories of cultural difference, specific aspects of Thai culture, and how to distinguish cultural stereotypes from appropriate generalizations. The essays in this Appendix use the Describe-Interpret-Evaluate (D-I-E) process for debriefing and analyzing cultural encounters in constructive ways. Recommended by intercultural learning and study abroad experts, this model guides learners to separate observable facts from interpretation and to delay judgment until multiple perspectives of the same events or behaviors have been identified and considered. By doing so they are more likely to be empathic and less likely to make incorrect interpretations and negative judgments that will limit their effectiveness when working internationally or domestically with people of different origins. Using this process can also help people manage the stress and frustration often felt in cross-cultural situations.

Relationships in Thailand
by Rose Colangelo

Every culture seems to handle relationships in different ways. In American culture, most people are not terribly secretive about their relationships as they hold hands in public and kiss on the street. However during PQP, I learned that in Thai culture this was not so. I knew that it was rare to see a Thai couple holding hands and even rarer to see them display more intimate affections. However, I did not know everything about the Thai view of relationships. Over the past two months of being in Thailand, I have had some experiences involving Thai people and their perspectives on how relationships should be handled.

One such experience occurred while we were on a boat floating down the Mekong River with friends and teachers from the schools we worked with in Sakon Nakhon. A Thai friend and I were conversing in Thai when I asked her if she had a boyfriend. She didn't directly answer the question and eventually told me that she didn't. Later, a Thai friend of ours told me not to believe her. When I asked why, he said that in Thailand relationships are considered a private topic, particularly among foreigners. He told me that if a foreigner asks a Thai person if they are single, the Thai person will always say yes.

Another such situation occurred in Kanchanaburi where we went to a party with group of Thai men. There were many Thai women at the party, but the men were mostly flirtatious with the foreign women at the party. Later, they wished for us to join them in their rooms. I told them that I had a boyfriend, but because he wasn't with me, they said I was single. They all said that they were single too, but we later found out from one of them that the Thai women at the party were their girlfriends. They also made many jokes about having multiple partners.

I asked a few Thai people why lying about relationships or having multiple partners seemed commonplace as the examples above are just a few of my experiences. A couple of my Thai friends told me that the topic of a personal relationship was private. They said that people like to be very discreet about their relationships and they may not like telling foreigners because foreigners may be trying to hit on them.

I was also told by another friend that since in some places it is okay to have multiple partners, maybe they would not admit they were in a relationship in hopes of having one with a foreigner as well. I was told that having multiple relationships was a way of showing status and wealth, so this may influence their decision to keep their relationships quiet as well.

When asked, another Thai friend of mine was shocked by the idea and told me that perhaps they are trying to get a foreigner as a partner. Yet another Thai friend expanded by saying that in some villages, particularly in the northeast, young women are encouraged to marry foreigners as they are normally wealthy. I've also heard from a few Thai women that Thai men don't treat women right and because of this, Thai women prefer foreign men.

I believe that in certain situations, the goal of someone lying about their relationship is to have a relationship with a foreigner. I have read and heard that it is generally acceptable for people to have more than one partner or to want a relationship with a foreigner. It seems to me that some Thai people don't have any problems with having multiple partners and expect their partner to be okay with that.

It also seems that many Thai people think that foreigners are rich and hard-working, so they would want a foreign husband or wife. Also, I think that many Thai people consider foreigners to be exotic as foreigners tend to stand out quite a bit in a crowd and light skin and hair is considered to be beautiful in Thailand. As an American, I do not like that people lie about being in a relationship. If I were their girlfriend, I would probably be offended if my boyfriend always denied our relationship. I also value a monogamous relationship.

However if I were part of Thai culture, I may not think it was so strange for many Thai people to be discreet about relationships or be okay with my boyfriend having multiple partners. I think that Thai culture is much more conservative than American culture. It seems like the reason for more discretion is based on Thai parents being conservative. Even after asking Thai people, I can't seem to find one reason why and it seems generational. As for having multiple partners, there are other cultures with similar beliefs. I learned from one of my Thai colleagues that when a man in China has multiple wives and many children, he is considered to be of a higher status. He is also seen as very wealthy since he usually has multiple households.

If I were from Thailand, I also may not think it was so strange that some Thai people may attempt to attract foreigners. I have noticed that many foreigners are also trying to attract Thais. I've been told that a relationship where a foreign man marries a Thai woman is usually mutually beneficial. I've also been told that a Thai woman would probably take care of him better than a foreign woman and she would also get the wealth and support of a foreign man. Just because they are from different cultures doesn't mean they won't love each other.

Although my beliefs oppose those of the Thai culture, I believe that the same social dynamics are still at play. Some young Thai couples can still be seen holding hands and sharing food at MBK and not everyone in Thailand believes in polygamy. As evidenced by news stories and Thai acquaintances, jealousy still comes into play in polygamous relationships as it would in America. Although the way in which Thai people handle their relationships will always differ from the way Americans do, the way people feel about each other doesn't seem to change no matter where in the world they are.

Fat
by Carol Okumura

The setting was at an extensive lunch table at around noon at the Baan Muang Wittaya School of the Kusuman District in Sakon Nakhon. Lunch had started at around 11:30, and as I walked over to find a seat, one of the female teachers grabbed me by the waist and asked the other teachers a question while pointing at me. The other teachers laughed and, being a little confused, I smiled and made my way to my seat. At noon, as I was about to serve myself a third plate of *khaw*, or white rice, the same teacher made a comment out loud to all the other teachers. The comment contained both my name and the word *khaw* in it, so I figured it had something to do with me and turned around to try to understand what was happening. The teachers laughed once again, and I heard my name along with the word *wuan* several times. Lee, our Thai-speaking group member from Chula University, was sitting right next to me and laughing the whole time as well. I asked him what they were saying, and Lee said "*Oh, nothing. I kind of don't want to translate it*." I then asked him the question, "*Does it have anything to do with being fat?*" and he replied with a simple "*Yes.*" The topic was then dropped.

It is safe to say, as a person that doesn't understand most of the Thai being spoken at the table, that the teacher talk over lunch period is almost two thirds laughter. The teachers, female teachers especially, like to tease around us *farang* students. When seen from a teacher's perspective, it is clear that this was not a name calling event. The teachers were mentioning my name loud enough for me to hear, and were looking at me the whole time, expecting me to laugh along with them. They seemed to be speaking slower than usual, expecting me to catch one word or two and understand the topic of discussion. They were also very casual, grabbing me by the waist and smiling a lot—as an attempt to make me feel comfortable enough to play around with them, and perhaps make me feel more at home.

From the point of view of us farang, however, things might have seemed a little different. Back in Brazil, where I grew up, most women are very careful about their weight. If you think someone is overweight, you refrain as much as you can from mentioning it to them—let alone make a joke about it in front of the whole table. Therefore, I thought it was a bit unusual that the teachers decided to make that type of joke and grab me by the waist in front of the whole table.

An interesting point of view to also be interpreted is my teammate's Lee. Out of everyone involved in the incident, he was the only one who *understood* both sides and was therefore put in a somewhat uncomfortable situation. It must have been difficult for him to find an appropriate way to describe what was happening at that moment. He said, in an attempt to clarify things, that this is "*the way Thai people joke around—they pick on you*" and I truly appreciated his efforts to make me understand the situation better.

Like most populations, Thais seem to give importance to body weight. I have lost count on how many 1 Baht scales I have seen outside (and inside) shops throughout both Bangkok and the Northeast. However, unlike at home, Thais do not hesitate in using body weight as an open joke.

And the teachers at Baan Muang Wittaya did so to create a comfortable environment with the foreign students. Each *farang* at Baan Muang Wittaya was picked on for something different: Sean looked sad all the time because he missed his girlfriend, Elias blabbered on how much he can speak Thai, Rose was always willing to eat anything that is put in front of her, and I was the one whose body shape is on the line for eating too much *khaw*. Thai people will joke around as much as they can in order to make their hosts feel at home. Teachers at our schools went above and beyond to provide us with good hospitalization—and apparently it was no different for the nickname hospitalization strategy.

Being that this encounter was new and unexpected to me, I had a difficult time knowing how to react to it. There were several teachers around, expecting laughter. I laughed a little, as I did to most of their jokes that I did not understand. I did, however, pick up on this one and for once felt like that small amount of laughter wasn't enough of a reaction. I was confused and many different thoughts ran through my head at once. One of them was a flashback to my childhood years. Growing up, I was a competitive gymnast and had my height and weight measured weekly by our team's coach. Weight was an important factor and we would rigidly be asked to lose kilograms: making it a highly regarded, sensitive topic. However, it also crossed my mind that not everyone at that table at Baan Muang Wittaya had Hilda as their coach telling them the importance of being thin while growing up. I had been the only one. Therefore, no teacher was aware of that initial shock I experienced upon first hearing their joke.

All the food they would feed me, how insisting they would be that I ate it, and how they picked on me for overeating—it was all connected, it was all part of creating a welcoming environment. I then decided to cover up that initial nervous laughter with a smile, as this clearly was no more than a cultural encounter in which my background and the teachers' clashed, requiring them to awkwardly exchange.

Euthanasia in Thailand and America
by Sean Patrick

The ethical treatment of animals is a controversial issue even within cultures. However, the cultural norms that define our behavior towards pets in the United States differ greatly from Thai standards of pet treatment. Most notably, Thai and American cultural norms differ on the euthanization of pets. This is readily apparent on the streets of Bangkok and other Thai cities, where packs of dogs – some clearly suffering from painful and debilitating diseases – roam freely.

One particular dog comes to mind. Dubbed "Rat-dog" by our group, he is a canine to whom the years have not been kind. Most of his unkempt hair is missing, revealing cracked skin of a reddish color. During cold spells, he wears a thin sweater. He barks at passersby and often attempts to pursue them, but is unable to do so due to an affliction of the hips or hind legs.

Rat-dog is not an isolated case. Another dog, whom we nicknamed Draggie, was the pet of one of our hosts in the province of Sakon Nakhon. He is, according to our host, 17 years old. Draggie acquired his nickname due to a condition of the hind legs which renders them unable to move, leaving him no other mode of transportation than being carried or dragging himself along with his forelegs. His eyes are cloudy with cataracts, and he often does not notice people passing by. His coat, however, is in good condition.

Other dogs come to mind. During my two weeks in Bangkok, I saw (as a rough estimate) around thirty stray dogs on the streets and campus of Chulalongkorn University. Although some of them were in good condition, many were suffering from skin diseases or were physically crippled. These dogs were not leashed and, although some had collars, most did not.

One interpretation of the situation of these animals is that animal control and health are not a priority in Thailand due to economic factors. By this interpretation, the animals are on the street are there because they have been discarded by their owners, and remain there because there are no institutions such as the SPCA or state animal control to euthanize them or put them in shelters. Animals such as Rat-dog remain alive because his owner (who, it can be deduced, is the one who put the sweater on him) cannot afford to spend the money to put him down.

Another interpretation is that Thai culture is inherently apathetic or cruel to domesticated animals, as evidenced by the practice in northeastern Thailand of eating dogs. Under this interpretation, animals are left on the street because their owners do not care for their well being and thus do not allow them into the house. Rat-dog and Draggie still live because their owners are apathetic to their suffering.

A third interpretation is that the dominance of Buddhism in Thai culture has lent it a tradition of pacifism and acceptance of suffering. Under this interpretation, Thai people are reluctant to euthanize their pets because they do not feel it to be necessary or kind. According to my Thai teammates, euthanasia is not encouraged in Buddhism; instead, suffering is valued as a part of life. Dogs live on the street because they must live somewhere, and to take their lives would be abhorrent. Draggie is allowed to live because even life that consists of suffering is better than its absence, and suffering is a part of life.

Although at first I found it hard to adjust to seeing animals left on the street, and left alive in their poor health, I can understand why it is not unusual in Thailand. I believe that the correct interpretation of the situation is a combination of all three of the above, in varying proportions. I believe that the Buddhist religion has influenced the treatment of animals, and understand the perspective that life is something to be valued and left unharmed. However, I also believe that there is a touch of cruelty in leaving an animal of advanced years alive only to suffer, and to sleep on the street. I believe that if more institutions such as animal shelters and veterinary clinics were in place, there would be less stray or sickly animals on the streets.

My personal belief on euthanasia is that it is an unfortunate necessity. I believe that it is inhumane to leave animals alive to suffer from agonizing diseases or crippling disabilities. I believe it is also necessary to control stray animals, in order to prevent the spread of disease and attacks on humans. I believe that the solution to the problems of animal treatment and control is the institutionalization of animal care, with shelters and clinics made more common.

I imagine that my beliefs would be slightly altered were I of Thai or Buddhist upbringing. I would probably see cruelty not in the prolonging of life, but in the termination of it. I might see suffering as a necessary part of life, and value it as a component of living. Were I Thai, I might be used to seeing dogs on the streets, and not see a need for more animal shelters or veterinary care.

However, the issue of euthanasia and animal rights is not one that is purely cultural, and rightly so. Within US culture and (I imagine) within Thai culture, views on proper animal care vary widely. Cultural differences are not as simple as a general statement such as, “Thai culture values life more than American culture.” Rather, it comes down to the individual decisions made by citizens of a culture, and the social repercussions of those decisions. People of neither culture want to be perceived as cruel, and people treat their animals according to their culture’s views on what is proper and kind.

Despite individual and cultural differences, there are some things which people of both cultures can agree upon. Institutionalized health care for stray and neglected animals is a desirable goal of both cultures and, although it may be realized more completely in the US, this does not mean that Thai culture is ignorant of pet needs. As Thailand’s economy develops, it is my hope that institutions for pet care will become more and more common. Neither culture wants to see animals suffer. Although its superficial manifestation may differ, compassion is universal.

Relationships and Signs of Affection
by Elias Whitten-Kassner

Relationships with people are very different when observed through different cultures. Thailand when compared to America has quite a few differences in people's relationships among one another. There are significant variations in professional, personal, friendly and religious relationships. One that has perplexed me the most is how people show affection or interest to another person in Thailand. It is important that I describe situations where I have experienced this than interpret and thoughtfully evaluate the issue.

The first significant difference that was noted upon arriving in Thailand was that Thai people of the same sex would be seen "clinging" to one another. By clinging I mean that one person would be holding onto the arm of another. It is hard to determine whether or not the people are just friends or if they are in a more intimate relationship just by their physical interactions. One thing I noticed is that there is a couple of different ways of holding onto someone. One way is by holding someone's wrist or arm and the other is by holding their hand.

The way people act towards others in a friendly encounter is seemingly different from my perspective of American actions. I observed a particular incident at Kanchanaburi where some Thai men in their mid 20's where drinking late at night and me and several others from the IQP group decided to introduce ourselves. The Thai guys were very friendly and they ask some of the girls if they had boyfriends. They also made a comment that they liked American girls.

Another event that follows this theme was also in Kanchanaburi. Three Thai girls went with us on this trip. One of the first questions I was asked by them was if I had a girlfriend. A few other people from WPI were asked this question as well shortly after meeting these girls. One of the girls was engaging in what would be considered flirting, in America culture, with some of the WPI guys. I later discovered that she was already in a relationship but despite this she continued flirting with the WPI guys. The other two Thai girls asked direct questions such as "Do you like her?" to the WPI guys although they had barely met these girls.

One interpretation of this is that Thai people are very friendly and none of the events described have any romantic inclination. Just because someone is touching someone else isn't an indication that there is a romantic undertone. Some Thais that I asked about this said that guys holding another guys arms and girls holding hands usually indicates friendship. However if the opposite sex is holding hands then it usually shows a more intimate relationship. I was told by going into someone's personal space it usually means that you are comfortable and feel a strong bond with that person. Flirting with someone could also just be a very friendly gesture in Thailand with no sexual inclination whatsoever. Asking someone if they have a girlfriend or boyfriend is a very common question among Thai people as explained to me by a Thai group member. Thai people seem to talk a lot about things that Americans usually find to be more personal information or inappropriate to say around people you don't know well.

My second interpretation is that Thai people act this way around Americans just because they think Americans act that way. There is a lot of portrayal of Americans as very touchy-feely people. Ads and movies show men holding onto one another when having a good time and women and men flirting even when in a relationship. Thai people may feel this is customary American behavior and thus act accordingly when around foreigners. People may feel that holding onto someone shortly after meeting them is an American way of showing you want to be buddies with someone.

A third interpretation is that maybe that these events are showing of romantic affection for someone in Thai culture. It could be that when someone is holding onto someone else they could be in a relationship or they could be close friends and there is no real differentiation between the two. When someone seems to be showing interest it is possible that they are interested in pursuing dating as was explained by one of our Thai students. In clarification of why some Thai girls flirt despite saying they have boyfriends, one Thai teacher at the Baan Muang Wittaya School said that it is common for Thai girls to say they have boyfriends solely to deter foreigners from liking them. I've heard a completely opposite explanation from a Chula student, in which girls will say they are single to marry a foreigner because foreigners are rich. Based on these two explanations it is possible that Thai girls will flirt with foreigners whether or not they lie about being in a relationship. This explanation doesn't explain the behaviors of the Thai men at Kanchanaburi, but it could be that despite being in a relationship people will still flirt.

In my personal evaluation of these events I find, rather than having a positive or negative reaction, myself mostly puzzled. I am somewhat unsure of what levels of relationships people have with one another. I find that even Thai people are uncertain about the relationship level of other Thais. They sometimes had no definite answer to why people act the way I observed and some people had mixed answers.

I find it a little strange that people hold onto each other so readily even without much of a heavy bond of friendship. I've both witnessed and had this done to me and in both instances I feel somewhat uncomfortable. Although I personally believe it is a Thai way of showing friendship because of my American background I cannot overcome my feeling of discomfort so easily. It is also hard for me to differentiate between who is in a relationship or not in the Thai culture. There have been times I assumed two Thai people were dating because of how much they made contact with one another, but I find out they aren't. This completely disorients my American perceptions on people being single or dating.

I feel confused on how Thai people show romantic interest in another person. In America people generally ask you if you are single if they are interested in you or know you very well. In my American experiences it is a bad thing for a person to flirt when they are already in a relationship. The actions of the Thai people I described are what I would define as flirting in America. It is very hard for me to know if someone is just being friendly or is actually interested.

I cannot say I have come to a final conclusion about the Thai culture when it comes to relationships. I try to keep a very open mind to new cultures. After speaking with Thai people about what I observed, I would probably find some of these events normal if I were a Thai person. In America specifically, I have been exposed to many different ways of building relationships with people from all the cultures I've interacted with. I feel that there is no real universal way to build a relationship, so I will have to continue to keep an open-minded view on this aspect of Thai culture in order to engage in building relationships with Thai people.

APPENDIX L. GROUP ASSESSMENT

For the preliminary portion of this project, our team consisted of four members. The group was first constructed at Worcester Polytechnic Institute, where initial research took place for a period of two months. This two-month period did not provide us with the chance to understand each group members' working strategies and personalities. The work during this preliminary portion of the project was mainly split between group members evenly. Each person knew his or her responsibilities, and the group would often meet for revisions. We worked effectively and met deadlines without encountering major problems.

Arriving in Thailand and welcoming two new members from Chulalongkorn University to the group changed the team dynamics to an extent. Our circumstances were unique, as we were sent to spend four weeks in the underdeveloped district of Kusuman soon after being introduced to each other. An understanding of team members' personalities or working preferences were never established prior to departure. We were completing the field work portion of this project as well as adapting to a new environment and living conditions, so we inevitably encountered some problems.

One of the problems encountered was **personality conflict**. We soon found that some group members required more personal time than others, and being somewhat forced to spend an extensive amount of time with the team hindered these members' productivity. This issue was quickly detected and resolved during our first team assessment session. By *developing a working schedule* and setting aside three to four after school hours (around 4-7 pm) free, team members would be able to separate work time from personal time in a professional manner.

A second problem we faced was a **group's drop in productivity**. We noticed that the adjustment to the sudden cultural, geographical, and living condition changes slightly dropped the group's productivity. Our working place was also our living place, making it challenging to keep focus. Our solution to this problem was to *assign group members specific roles*. Roles varied depending on the day and became more defined as we discovered our strengths and weaknesses. This resulted in great improvement in our group's productivity and it was seen even clearer after arrival back in Bangkok.

Completing the field work portion of our project by living and working together affected our team dynamics in many positive ways, showing great **improvement in problem solving**. Group members learned about other members' personalities and most importantly, how to work effectively with them. Communication was more effective as well, with little to no arguments among group members, different from our first week in Sakon Nakhon.

We realized there was a lot of unproductive back-and-forth arguing, especially after arrival at field work site. After our first assessment as a team, however, we came up with a few strategies to solve this. We held discussions on how important it was to respect each person's working strategies, and created rules on problem solving such as: during an argument, the same person was not allowed to speak until everyone else got the chance to. Though these were effective methods, our group did not go through many major arguments after that first assessment, and gradually realized there wasn't as much need for assessment as there was at first—which we took as a positive finding.

In our case, it was concluded that our teamwork conditions highlighted the boldest aspects of each member's personality. Though this fact brought the group off to shaky start, we quickly caught on it and used it to our advantage. Towards the final stage of the project the group worked more effective than it ever had before, completing the final report in no rush, and in a most professional manner.

Individual Assessment – Members from Worcester Polytechnic Institute

Rose Colangelo

Over the past four months working with WPI team members and two months working with Chulalongkorn team members, I feel that I have gained significant teamwork experience. Originally working with three other WPI students, our team was very solid as we worked toward deadlines and met them. My work then was fairly cut and dry – we split up parts of an assignment, wrote them, and reviewed them together. After arriving in Bangkok, meeting our Chulalongkorn group members, and adjusting to a new environment, our team dynamic changed significantly. I learned that working as a team in a field work environment was much different than just writing a report together.

After arriving in Sakon Nakhon, we began to live together, which made it difficult for me to separate work and down time. I would often get frustrated if group members didn't work during scheduled work time, and we were working in the same space we lived in. In other situations, I may not get so defensive and be more open to discussion, but in the situation we were in, I found myself occasionally becoming defensive of my contributions to the team

My attitude has improved greatly since we've gotten back to Bangkok as I have learned how to take constructive criticism better without argument. My effort in Sakon Nakhon was not as good as it could have been because of the work-home environment. I did not try as hard in my home environment. However, if I said I would do something, I always got it done but would not go out of my way to find assignments. My group feels that my effort has significantly improved over the past few weeks. My group and I have noticed that I have set out to do tasks without being asked and get them done reliably.

One aspect of my work that seems to have been consistent is that I always am very opinionated and try to take the ideas of others into account. Sometimes I can be dismissive of others ideas, but I try my best to consider them and provide constructive, unbiased feedback. For a while, Elias and I would argue over minor details, but that was remedied after our first teamwork assessment. The way we fixed this problem was to just become more open-minded and less argumentative. When we were practicing our presentations, I tried to give as much constructive feedback as possible to help make our presentation better. I also am very good at noticing the strengths and weaknesses of not only my peers but of myself and I try to stay objective about them. During previous teamwork assessments, when assessing myself I would often notice my strengths and weaknesses before my team pointed them out to me. When I realized I could do this, it helped me to notice my problems and improve them later on. Overall, my group and I feel that I have continually tried to improve.

Carol Okumura

Upon completing this project, it was concluded by me that our group was provided with the *extreme teamwork experience*. This proved to be productive, as it allowed me to highlight strong aspects of my working style as well as learn to overcome difficulties.

I learned that giving our work conditions, it was very important to work in a calm, unrushed manner. This proved to be my main obstacle for me at first because I tend to be hasty in approaching my tasks. I'm very goal-oriented, and once I'm provided with a task, I want to quickly accomplish it and jump on to the next. In a few occasions, this led me to rapidly lose patience with other team members, as I would get easily overwhelmed fearing parts of the project would not be completed. After this was pointed to me during teamwork discussion, I tried to work on it by providing myself and the other team members the necessary personal space to complete their tasks. I came to realize that by working effectively as a team, things *will* get done and there was no need to make myself anxious about it.

I was told by the group, however, that I'm strong in taking the initiative and leadership roles. As an example, I took the lead in tasks such as compiling the final report and presentation material, as well as a couple of cultural exchange activities. Due to my working style, I also made sure I communicated well with other team members in order to continuously have an overview of what each person was working on. This was very important to me, as I learned that I'm the type of worker that constantly needs to see the big picture in order to assess the overall progress of the team.

Though it is difficult when working this closely with a team, I try my best to keep an open mind. I sometimes tend to rush into expressing my thoughts and taking the lead. This, once again, led me to learn the importance of taking my time in analyzing situations before quickly jumping into them. This is the characteristic in which I worked the hardest to improve during this project. I did so by constantly trying to keep comments to myself despite the urge to speak up. I was told, however, that this was also seen as a positive attribute, since I was very reliable in constantly providing the group with feedback.

According to our assessment, the group believes I'm strong in providing the group with constructive criticism, as well as take them in fair manner and accepting manner. The main lesson I learned was how to try and differentiate working styles, and handle them accordingly. It was by doing so that group members, including myself, were the most productive.

Sean Patrick

Throughout my time working on this project, I have drawn various praises and criticisms from my peers. Their comments and suggestions have been very helpful in not only helping me assess my teamwork style, but also in helping me to improve my teamwork skills. Through working with them, I feel I have learned a great deal about how best to work in a team. I am very grateful to have had the opportunity to work with them.

According to my teammates, I think deeply about criticisms and make good efforts to improve upon my weaknesses. Although I can be stubborn about certain points, I generally am accepting of criticisms and willing to change. However, because I think deeply about criticisms both of myself and others, I am often hesitant to share my feelings with the group. Although I agree or disagree with others who share their opinions, I am rarely the first to bring up an issue.

During the course of this project, one of my greatest weaknesses has been my inconsistency in leadership. During my time in Worcester I took on a leadership role and my teammates came to expect leadership from me. When that leadership disappeared in Thailand, they were unpleasantly surprised. Recently I have taken steps to remedy this problem such as making an effort to be more organized and take on more work, but my leadership is still inconsistent and comes and goes unexpectedly.

My ability to focus has also been poor during the project. I was easily distracted while working, and during meetings I tended to drift off and not pay attention. Although I accomplished my goals on time and to a satisfactory extent, I could have contributed much more fully to the group had I been more focused. Although I have attempted to improve this weakness by, for instance, closing instant messenger programs while working, it is still an area I can improve upon.

My greatest strength during this project has been my reliability, according to my teammates. When asked to do work, I do it thoroughly and consistently. Although the quality of my work varies, it is always acceptable, and my work is always finished on time.

Overall, my experience working with this team has been very positive, and I feel that I have learned a lot from working with them. I have learned that, although I enjoy working in a leadership role, I need to be able to maintain that leadership even in unfamiliar situations. I have also learned that individual personalities can vary greatly within a group, and it is important to be tolerant of personal differences and make sure people have enough space. Finally, I have learned the value of cooperation and team synergy, and have witnessed firsthand the effect of the whole being greater than the sum of its parts.

Elias Whitten-Kassner

Over the course of this project I have learned a lot about teamwork and myself as an individual of a team. I learned the most about these issues during the field work portion of the project. We spent four weeks not only working with each other but living with each other. This added a whole new dynamic to the way the team performed. There were several problems that arose in the team that were useful learning experiences on how an effective team works and about myself as a team member.

Some of the key aspects I learned about a team involve the relationships between people in the team. A team should separate socializing from work especially if they are living together. This was important because I found members of the team became annoyed with other teammates just from prolonged time together. It is effective to a team's productivity during work hours to have time away from each other. Teams should also have assigned roles for everyday of work. If this does not happen the team's work output drops because people are spending too much man power on some tasks and not enough on others.

My team said that I was a helpful asset to the team for several reasons. I have good communication with the rest of the group and always know what needs to be done. I always informed other group members of what I was planning to accomplish that day. I take initiative on what needs to be done and rarely needed any of my group members to find an assignment for me. I always was involved in some form of work during fieldwork as I would often find cultural exchange activities to engage in if no other work was required. During teamwork assessments and work hours I am open to speaking my mind on what I think or feel. By this means I constantly gave constructive criticism to my teammates and support their improvement efforts.

Several weaknesses have hindered my effectiveness as a group member. Although I took the initiative on a lot of the report, sometimes I would do too many revisions on the report at once and my group members felt I was trying to focus on too many things at once. I have always been stubborn and in the team this made it hard for me to be open-minded with other group members' suggestions. Many times I would debate over changes to drafts that others made that weren't necessarily important. This sometimes resulted in more conflict than was necessary in group discussions and slowed down productivity in writing.

I spent a lot of thought on improving aspects of myself as a team member that were detrimental or that I was uncomfortable with. I feel that I have grown more confident in expressing my opinions and at taking initiative throughout the course of this project. I also have gained some improvement in my stubbornness and have gotten more comfortable with taking others opinions into consideration with my own. Although I have improved I still need to work on being open-minded for further projects. I have become overall better at talking to my group members about conflicts.

Individual Assessment– Members from Chulalongkorn University

Veerada Thammasunthorn

Being a part of the IQP project in Sakon Nakhon has given me the opportunity to experience teamwork like I never have before. There is more challenge in doing this project compared to all the projects I have completed in the past because team members were working, living together, and at the same time constantly getting to know each other and also other people in the same environmental setting. During the first week, all of us faced the same challenge of adjusting and it was especially difficult to know what to expect from the other team members and vice versa- what they expected from me. As time progressed, the team became more familiar with each other's personalities and perspectives and became more accepting and understanding. This was a great relief for me as I personally felt that the first week was very intense because I wasn't being myself at all. I remember in my first teamwork assessment where team members commented that I was very reserved and would prefer if I expressed my feelings and opinions more.

As soon as I was able to cross over that barrier, I felt that I have improved greatly in giving opinions and expressing how I feel. However, group members still felt that I was not expressive enough because I don't give many constructive criticisms and don't conflict as much with team members (too passive). When I am about to oppose an action/opinion and begin to feel that the other person is getting intense, I would simply tell myself to stop and let the other person try what they think is best. I have learned that it is very important to have self-control and self-awareness when working together as a team. In addition, I was told that I was a good listener and also good at emotional support.

In terms of work, team members felt that I put good effort and produce high quality work. I would get one thing done at a time, which sometimes led to putting too much focus on a particular task. Perhaps, this was due to how I was trained. Other than that, team members said I was good at organizing and very reliable when it comes to getting work done. I was also good at coordinating with people.

When we came back to Bangkok, we shifted our focus from doing a lot of field work and social interaction to finalizing our report and presentations. I felt that everyone worked very hard and more seriously as we were pressed with the amount of time we had left. Despite all the challenges and conflicts, I can proudly say that there was a good ending to our project with many good memories to bring back and share.

Leu-Shyue Chen

Through the project, I was able to realize the importance of teamwork and discover methods for an efficient teamwork. My team's criticism and support have been helpful in identifying improvements I have to make and taught me about efficient teamwork. I am grateful to have the opportunity to work with them on the project.

Initially, my teammates felt that I was too relaxed about the project. This was probably due to my personality and how I wanted to have fun while working on the project. Over the course of the time spent on the project, I tried to change this image about me by taking initiatives during the fieldwork portion of the project and developed a working schedule for our group. Furthermore, I believe that I have not contributed much towards writing before our fieldwork and therefore tried to have a bigger role in writing the report. Group members also note that I put a lot of effort into work but it was not always reliable. Sometimes the writing section I worked on would be sent out later than expected or did not include all the changes we discussed about. Additionally, sometimes simple tasks like printing out our presentation would be forgotten until the deadline was near. Another weakness that hindered my contribution towards the project was my patience. Team members think that I am still hot-tempered and impatient at times. I tried to address this by keeping statements to myself or work on something else while waiting for others.

According to my teammates, my main strength is that I am a strong communicator with good socializing skills as I had little difficulty starting conversations with people. I represent the following attribute through activities such as socializing within the group, coordinating with the teachers and leading focus groups. Team members also felt I was a good listener and I took criticism very well. This finding was found during our team discussions and during our meetings with the advisors where I was able to incorporate their criticism to improve my work. Lastly, it was stated by my team members that I gave constructive and actionable feedback to other team members. During our team discussions or practice for presentations I would always have something to say that would help develop some ideas or point out things that could go wrong while also taking people's arguments into account. However, sometimes I would make a statement that was too direct and would seem harsh to some group members.

In conclusion, it was a very positive experience working with this team. I felt I have absorbed some of their working ethics as well as thinking in another way. I have learned that taking the initiative is great but it is better if everyone is on the same page as you. I have also learned that through careful planning, one can modify their behavior to a certain point. It was also found that different personalities required different treatments and understanding them was important to build an efficient system in the team. Finally, I was able to appreciate the importance of teamwork and how efficient it could be.

APPENDIX M. LAB MANUAL

WORCESTER POLYTECHNIC INSTITUTE
CHULALONGKORN UNIVERSITY

Science Laboratory Manual

Lab examples and design instructions

Leu-Shyue Chen

Rose Colangelo

Carol Okumura

Sean Patrick

Elias Whitten-Kassner

Veerada Thammasunthorn

Sponsored by The Office of Her Royal Highness Princess Maha Chakri Sirindhorn's Projects

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TEACHER'S GUIDE

LAB DESIGN

RECOMMENDED LAB DESIGN

Lab activities for the Kusuman district schools are recommended to be designed with these four criteria in mind.

- *Engaging and hands-on*: The research of relevant literature showed that in order to engage students in science, lab activities must include student participation as opposed to simple demonstration.
- *Follows curriculum and appropriate difficulty level*: The labs designed should be used in conjunction with an appropriate lesson plan for effective learning results and retention of information.
- *Relevant to students' lives*: In order to increase student interest and engagement, it is important that lab activities be relevant and applicable in students' daily lives. This will increase students' awareness of the importance of science.
- *Inexpensive and rely only on local materials:* Budgeting money for a lab activity is usually a problem for many schools. If lab activities are designed to use locally available and cheap materials it will be easier to implement the lab in the long term.

Designing a lab activity from scratch is time consuming and must be tested many times to assure that it works. It is a lot more time effective to use pre-existing lab activities that have been formally tested and then modify the experiments to better follow the criteria listed above.

To find lab activities there are several places to find them. The internet is highly recommended for finding lab activities. The internet has many lab activities available and the majority of sites are free. The next best place is within textbooks or other lab manuals. The problems with these sources are that they cost money to buy or the experiments in the manuals are expensive to conduct and won't work without the materials stated in them.

Student handouts should be designed to include, the background information, objectives, materials, procedure, observations and data collection, and questions. The questions should be formatted in a way that students will be able to relate to the exercise they did as well as the information from the background.

SIMPLIFIED STEPS TO LAB DESIGN

Step 1: Decide on a topic – Topics should be covered in class at least a day before introducing a lab.

Step 2: Research the topic – Use resources such as books and the internet,

Step 3: Brainstorm and Research labs – Look through labs that are relevant to the researched topic and that can be used in class,

Step 4: Lab selection – Select 1-2 labs that could be conducted with the equipments available in class or items that could be easily be found in the local area.

Step 5: Modifying labs – If the labs do not fit the four criteria listed previously then modify the lab to better fit the criteria by changing materials, procedures, and developing questions.

Step 6: Write up the material list, procedure, and questions for the lab.

Step 7: Buy materials – If needed.

Step 8: Test the lab – Make sure you test the lab before trying it in class.

Step 9: Modify the labs – This is necessary if there were problems with results in step 7 once modified repeat step 7or if the lab doesn't work at all it may be better to discard the lab and go back to step 3.

Step 10: Test the lab again.

Step 11: Write up the finalized material list, procedure, and questions for the lab.

BIOTECHNOLOGY BOARD GAME

Designed for Matthayom 1 students

BIOTECHNOLOGY GAME GENERAL INFORMATION

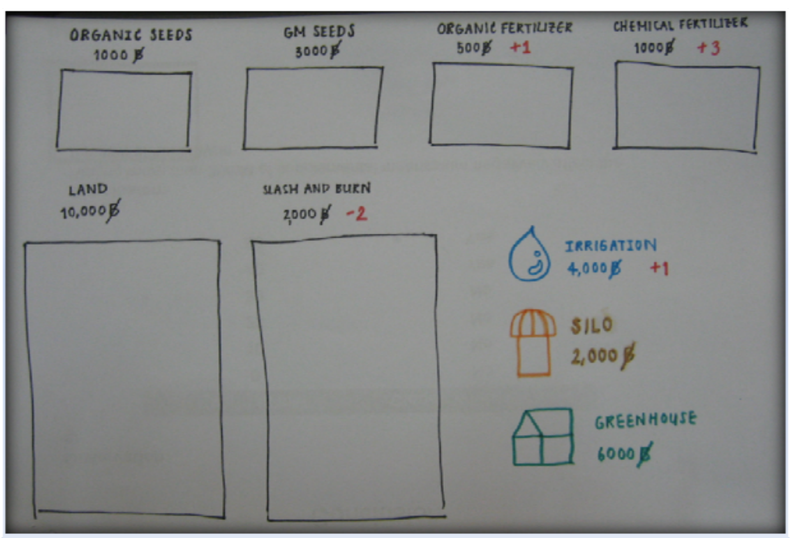
The biotechnology board game is a game designed to teach students the difference between growing organic crops and genetically modified crops with a small farm. It teaches how irrigation and fertilizer are helpful in farming and if combined increase farm output substantially. The Biotechnology board game requires few materials and the game is simple to implement. However, it is important to note that because the game is conducted with dice the game is based off chance to an extent and therefore the results may be different than what was trying to be conveyed.

TO PREPARE

- Have students cut out game pieces if needed.
- Split students into groups of no more than six students per group

MATERIALS LIST AND PROCEDURE

- Biotech board game
- Paper
- Dice



Biotech Board

GAME RULES

STARTING THE GAME:

- Each student begins with an initial 10,000 Baht and two plots of land at the start of round 1.

- Each round has 3 phases:

    - **Purchase of Materials** - In phase 1, players may buy materials from the items list (below.) The limit is of 2 items per round, because of shipping limitations**.**

Items List

ORGANIC SEEDS

1000 baht

Roll on the Organic growth table for one plot of land. You may grow one organic crop next round without buying more seeds (you use the seeds from this crop) as long as you are not cross-contaminated and have enough plots of land.

GENETICALLY MODIFIED SEEDS

3000 baht

Roll on the GM growth table for one plot of land. Beware of cross-contamination – whenever you grow a GM crop together with organic crops, you must also roll on the cross-contamination table. Note that you must buy GM seeds *each round* in order to grow GM crops.

ORGANIC FERTILIZER

500 baht

+1 to your growth roll for one crop on the dice roll table for one round.

IRRIGATION

4000 baht

+1 to growth rolls for one plot of land for the rest of the game.

SILO

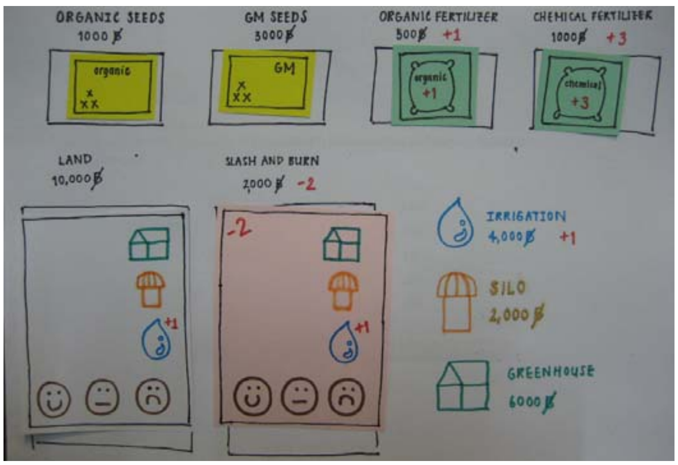
2000 baht

You may sell one extra crop per silo per round. This means that with one silo you can sell 3 crops per round, with 2 silos you can sell 4 and so on.

ADDITIONAL LAND

10000 baht

You may grow one extra crop per round (per plot of additional land) for the rest of the game. You may have a maximum of 5 plots of land.



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- **Growing Crops** - In phase 2, players roll dice to determine the success of their crop growing season, using the dice roll tables (below.)

Table 1: Organic Growth

Dice Roll	Result
1	There is a severe drought. You cannot sell the crop, and it doesn't produce seeds.
2	Your crop is eaten by insects. You cannot sell the crop, and it doesn't produce seeds.
3	You grow just enough to feed yourself. You don't make any money, but the crop produces seeds that you can use next round.
4	Your crop produces a minimal yield. You can sell the crop for 2000 baht.
5	Your crop produces an average yield. You can sell the crop for 3000 baht.
6s	Your crop produces an above-average yield. You can sell the crop for 4000 baht.

Table 2: GM Growth

Dice Roll	Result
1	There is a severe drought. You cannot sell the crop.
2	Your crop produces minimal yield. You can sell the crop for 2000 baht.
3	Your crop produces an average yield. You can sell the crop for 3000 baht.
4	Your crop produces an above-average yield. You can sell the crop for 4000 baht.
5	Your crop produces an above-average yield. You can sell the crop for 4000 baht.
6	Bumper crop! You can sell the crop for 5000 baht.

- **Selling crops and materials** – In phase 3, players redeem their crops for more money and may sell back any materials they don't want. The limit is of 1 item and up to 2 crops, due to shipping limitations. If players want to sell additional crops, they must buy a silo per additional crop to be sold. Any crops not sold are lost at the end of the round.

During the game

The cost of items sold back is always 50% of the original price during the game.

Ending the Game

- The game ends after 10 rounds.
- At the end of the game, add half the value of each of your other items - such as irrigation, greenhouses, and slash & burn land.
- The winner is the person with the most money added up.

Value of Items and Land at end game

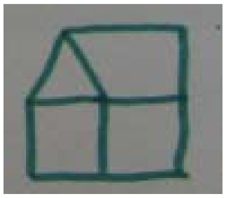
Items/Land	Value (Baht)	Extra end game rules
Land	8000	Deduct 1000 baht for each soil depletion marker on the land.
Silos	2000	
Organic Seeds	2000	You can only sell 1 organic seed. Each additional silo allows the sale of 1 more organic seed.
Irrigation System	2000	

OPTIONAL ITEMS/RULES

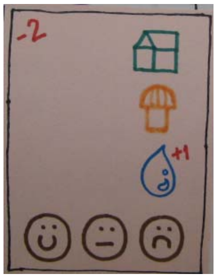
The optional items and rules listed below can be used to teach additional agricultural concepts to the students. These rules may make the game more complex so it is recommended to play the normal game before applying these changes. You can choose which rules you want to implement for your class.

OPTIONAL ITEMS

CHEMICAL FERTILIZER – 1000 baht - +3 to your growth roll for one crop on the dice roll table for one round, but your soil becomes depleted faster and you must add 2 X's for soil depletion instead of one X. (See Soil Depletion in special rules)



GREENHOUSE – 5000 baht. Voids the cross-contamination rule. (See Cross-Contamination in special rules)



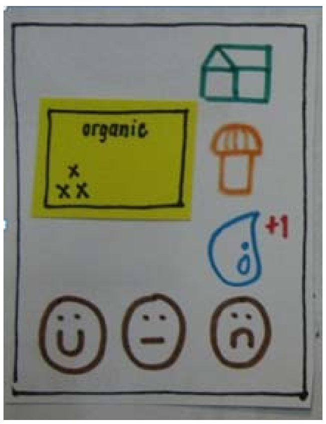
"SLASH AND BURN" – 2000 baht – Same as additional land, except that crop growth and soil depletion rolls are made at a -2 penalty on this plot of land. Mark any "slash and burn" plots with the letters "SB" to remind you of this penalty.

OPTIONAL RULES

CROSS CONTAMINATION CARDS

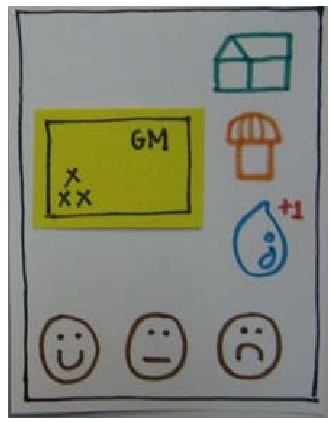
Cross contamination occurs when GM crops pollinate organic crops, making them sterile. If you have both GM and organic crops, you must pick up a chance card to determine if cross contamination will occur.

Solution: Greenhouses will prevent cross contamination and helps avoid the chance cards.



If there are no greenhouses,

Players must pick up the chance card to see if cross contamination will occur



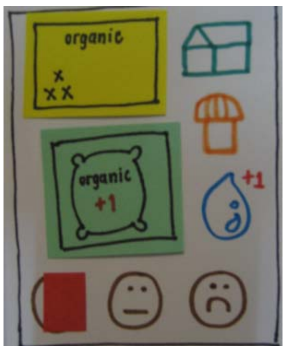
Examples of chance cards:

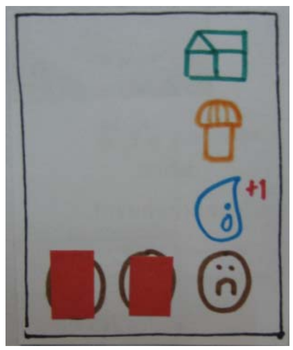
GOOD! Your crops are not affected by cross contamination.

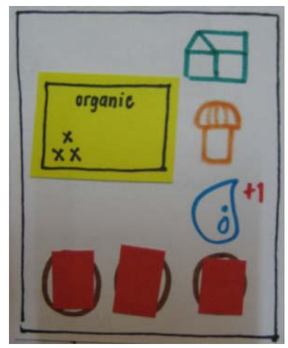
BAD! Your crops have become sterile through cross contamination.

SOIL DEPLETION

Soil depletion occurs when the natural nutrients and beneficial microorganisms of the soil are used up or destroyed, making the soil bad for growing plants. If a plot of land is used to grow crops for 3 seasons in a row without being rotated, or if chemical fertilizer is used, there is a risk of soil depletion. Every time you grow a crop, put a soil depletion marker on that plot of land. When you have accumulated 3, you cannot grow crops unless you pay 3000 to remove all the soil depletion markers. In addition, you cannot use this plot of land until the next turn. You must spend 1 turn growing no crops on any plot of land that is depleted in order to recover. A suggested strategy is to rotate your crops, leaving alone 1 plot of land each turn to restore its soil.



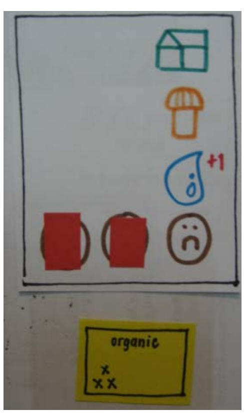




Players must put a soil depletion marker on the land they used to grow their crops

If chemical fertilizers were used on any land, players must put two soil depletion markers on that land.

3 Soil Depletion markers indicate that the land is unusable. A fine of 3000 baht must be paid to restore the land and it cannot be used



If the land is unused for 1 round, the soil recovers. Players will be able to remove the soil depletion markers.

OUTCOMES AND PROBLEMS

- Students that grow only organic crops with irrigation should win the game (in theory).
- Probability will affect outcomes.
- Students will try to make up rules while playing the game, a small group should be taught beforehand to make it easier for other students to understand the game.
- Students should be reminded to put markers for soil depletion.
- Students should be reminded to pay for buying resources or items.
- Students should be reminded to return GM crops and fertilizers to the shop after each round.

GROUNDWATER LAB

Designed for Matthayom 2 students

GROUNDWATER LAB GENERAL INFORMATION

- Groundwater Model - In the groundwater model lab students will design their own groundwater system using rocks sand and soil with two wells and observe how groundwater flows through the ground and see how contaminants flow through groundwater and into wells. Students should see that contaminated groundwater will be drawn through the well and will move quickly through the groundwater supply. It is also possible to build a groundwater filtration model to demonstrate to the students (See optional filtration model procedure).

- Measuring of pH in native water lab - The students will test samples of native groundwater, purified water, and tap water using litmus paper. This will allow them to see how acidic or basic their water supply is. Acidic water can cause health problems by the corrosion of metal pipes and negatively affect growth of plants. This lab is designed to be used with the earth science lessons in the M2 class. It is recommended that you use this lab following a lecture specifically on groundwater and groundwater systems for optimal learning results.

OBJECTIVES

- Students will observe how groundwater flows in a groundwater system
- Students will learn how contaminants seep into groundwater.
- Students will test groundwater and public supply water for pH.

TO PREPARE

- Get samples of groundwater, pond water, and purified water and test pH of each yourself so you know the values students should be getting.
- Break students into groups of six.
- Have students collect rocks, sand, soil, and water samples.

Part 1: Groundwater Model

http://www.ec.gc.ca/water/en/nature/grdwtr/e_gdwtr.htm

MATERIALS LIST

- Sand
- Soil
- Rocks
- Medium and small gravel
- Water
- Food coloring
- A clear shoebox container
- 2 Plastic straws
- 200 mL Beaker
- Syringe

PROCEDURE

- Pour big rocks on the bottom of the container so that the whole bottom is covered
- Place medium sized gravel on top of the rocks and level out smoothly then cover with small gravel and level.
- Hold two straws vertically in place, inside the gravel.
- Add a layer of sand above the gravel and leave some space for soil.
- Cover sand with chosen amount of topsoil making sure to not over fill container. (Note: the ratio of soil to sand to rocks should be 1:1:4)
- Slowly add water to the soil until the water reaches the top of the gravel and rock layer.
- Use syringe to draw water from the straws and observe what happens.
- Slowly add 200ml of water with food coloring to the top of the model until you observe green water flowing into the rock layer.
- Use a syringe to draw water from the two wells and observe how the contaminant moves through the water.

OUTCOMES AND PROBLEMS

- Water should flow down through the soil and sand and sit in the rock layer. The more water you add the water level should raise, saturating the model from the bottom to the top.
- Food coloring contaminants should move through groundwater quickly when drawn through the wells.
- If students cannot see food coloring when they draw water through the straws add a more concentrated mixture of food coloring.

Part 2: Measuring pH in Native Water

http://www.hach.com/fmmimghach?/CODE:LG0045861|1//true

MATERIALS LIST

- Three 200 ml beakers
- Well water
- Pond Water
- Purified water
- pH paper

PROCEDURE

- Fill 200 mL beaker with 100 mL of well water.
- Test water pH with pH paper and record color change.
- Look on pH scale for numerical value.
- Repeat steps 1 – 3 for pond water and purified water.

OUTCOMES AND PROBLEMS

- Pure water should be neutral.
- Groundwater and pond water should have a non neutral pH value.
- If groundwater and/or pond water have a neutral pH value of 7 it may be because of additives to the water that are balancing out the pH.

OPTIONAL LABS

There are two labs that can be used in conjunction with or done before the groundwater lab to increase students understanding of concepts presented in the lab. Both optional lab procedures can be found under the optional lab procedures section of the lab procedures.

- Permeability lab –This lab is designed to show how fast water flows through different materials and grain sizes of earth. Students will gain an understanding of what permeability is with a laboratory experience.
- pH lab – The pH lab is designed to improve students understanding of the pH scale and how pH paper works. It is recommended that a lecture on the pH scale is conducted before doing this optional lab.

Optional Lab #1 : Permeability Lab

MATERIALS LIST

- Sand
- Soil
- Small Gravel
- Water
- Filter paper
- Three 200 mL Beaker
- Syringe
- Funnel

PROCEDURE

- Fold the filter paper into quarters and open so it's a cone. Place cone filter paper into a funnel and place onto beaker.
- Add gravel to the funnel so that it is half way full.
- Repeat steps 1 and 2 for sand and soil.
- Add 50ml water into the three funnel at the same time using the syringe and wait for one minute and observe the flow rate of water.
- Measure amount of water in each beaker after one minute and record on table.

OUTCOMES AND PROBLEMS

- Gravel should be the most permeable and absorb the least amount of water.
- Sand should be the least permeable.
- Soil could be less permeable than sand in this test if the soil is either extremely absorbent .or if the soil becomes clay when wet. In any case explain why the substances had the permeability that they exhibit.

Optional Lab #2 : pH Lab

MATERIALS LIST

- Lemon Juice
- 200 ml beakers
- Lye soap
- Water
- Table salt
- pH paper

PROCEDURE

- Fill 200 mL beaker half way with water.
- Place pH paper into water and record color change.
- Look at pH scale and determine numerical pH value.
- Empty beaker and refill halfway with water.
- Add 50 mL lemon Juice.
- Repeat steps 2-4.
- Add packet of Table salt.
- Repeat steps 2-4.
- Add shavings of Lye soap to water.
- Repeat steps 2 and 3 then clean beaker.

OUTCOMES AND PROBLEMS

- Lemon juice water should be acidic with a pH of around 3.
- Soap water should be basic with a pH of between 9-12.
- Salt water should be basic around 8.
- Neutral water should be neutral around 7.
- If you are using water from a local groundwater supply the pH of neutral water will be a little below 7. This will also offset all your pH results for the other substances so be sure to explain the offset to the students so they understand why they are getting different pH values than expected.

BATTERY LAB

Designed for Matthayom 3 students

BATTERY LAB GENERAL INFORMATION

- Lime Battery - In the lime battery lab, students will create their own electrical circuit systems using limes, strips of copper or equivalent copper coins, strips of zinc or galvanized nails, aluminum foil, tape, and light-emitting diodes (LEDs).
- Salt Water Battery - In the salt water battery lab, students will create their own electrical circuit systems using beakers, water, salt, strips of copper or equivalent copper coins, strips of zinc or galvanized nails, aluminum foil, and light-emitting diodes (LEDs).
- Burning Up A Diode - A demonstration performed by the teacher to show the students the hazards of electricity.

OBJECTIVES

- Students will learn how to build an electrical circuit.
- Students will learn to tell the difference between electrolytes, electrodes, cathode and anode.
- Students will learn how to use Ohm's law.
- Students will learn about the hazards electricity could bring.

TO PREPARE

- Prepare salt water and separate the materials for the class.
- Break students into groups of six.
- Revise Ohm's Law with students.

Part 1: Lime Battery

http://hilaroad.com/camp/projects/lemon/lemon_battery.html

MATERIALS LIST

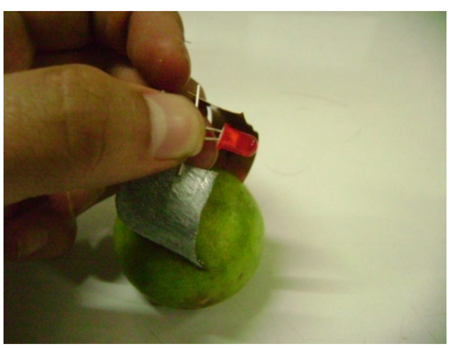
- Limes (4 Per Group)
- 4 Strips of Copper or Equivalent copper coins
- 4 Strips of Zinc or Galvanized Nails
- Aluminum Foil
- Tape
- light-emitting diodes (LEDs)

PROCEDURES

1) Place the copper strip/coin into one side of the lime.
2) Place the zinc strip/galvanized nail into the other side.

   Note: Make sure the zinc and copper do not touch inside the lime!!

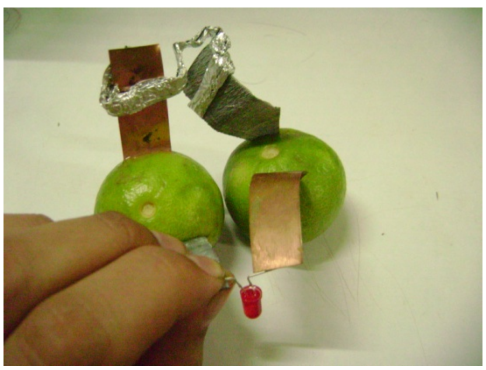
3) Attempt to light up a light-emitting diode by attaching the + side of the LED (the one with the longer wire) should be connected to a copper strip or coin, and the aluminum attached to the zinc to the – side.



4) Repeat steps 1-2 with the limes, so you have 4 lime batteries.

5) Connect the copper on one lime to the zinc on the other lime by using the aluminum foil to link them together. Use tape if necessary. Leave the limes at the end unconnected but with long strips of aluminum foil attached.

6) Now connect the two strips of aluminum foil to that of the LED. The + side of the LED (the one with the longer wire) should be connected to a copper strip or coin, and the aluminum attached to the zinc to the – side. Observe and record what happens.



7) Connect the LED backwards, so that copper goes to – and zinc to +. Observe and record what happens.

8) Remove the aluminum foil and metal pieces so you can use them in the next part of the experiment

Part 2: Salt Water Battery

MATERIALS LIST

- 4 x 50mL Beakers
- Water
- Salt
- 4 Strips of Copper or Equivalent copper coins
- 4 Strips of Zinc or Galvanized Nails
- Aluminum Foil
- Tape
- light-emitting diodes (LEDs)

PROCEDURES

1) Add water to the four 50mL beakers until they are almost covered.
2) Add a large amount of salt into the solution and stir.
3) Fold the metal strips into half.
4) Place the copper strip/coin onto one side of the beaker.
5) Place the zinc strip/galvanized nail into the other side.
   Note: Make sure the zinc and copper do not touch inside the beaker!!
6) Repeat steps 1-2 until you have 4 salt water batteries.

7) Connect the copper on one beaker to the zinc on the other beaker by using the aluminum foil to link them together. Use tape if necessary. Leave the beakers at the end unconnected but with long strips of aluminum foil attached.

8) Now connect the two strips of aluminum foil to that of the LED. The + side of the LED (the one with the longer wire) should be connected to a copper strip or coin, and the aluminum attached to the zinc to the – side. Observe and record what happens.
9) Connect the LED backwards, so that copper goes to – and zinc to +. Observe and record what happens.

Part 3: Burning Up A Diode

MATERIALS LIST

- 4-5 C type Batteries or a D type battery
- Tape
- Aluminum Foil
- Tape
- light-emitting diodes (LEDs)
- Tweezers

PROCEDURES

1. Connect the batteries by using tape till they are arranged into a straight line.
2. Attach aluminum foil to the ends of the lined up batteries with tape.
3. Hold the LED with tweezers and attach it to the strips of aluminum foil.
4. Wait till the LED burns out and let the students observe the difference between a fresh LED and burnt one.

SAMPLE STUDENT HANDOUTS

BACKGROUND INFORMATION

Agriculture is one of the oldest technologies in the world, but new technologies are always being invented for use in agriculture. Farming has been improved a great deal since the beginning of agriculture by new inventions. Some of these inventions are complicated, like farm machinery and genetically engineered crops. But some of the most important farm inventions are simple.

One of the simplest farm techniques is the use of fertilizer. Since ancient times people have used manure and rotting food as plant fertilizer, and it is a very effective way to improve crop yield. Recently, new chemical fertilizers have been invented that give better results than organic fertilizers like manure. Unfortunately, the environmental effects of these fertilizers are very severe, causing problems in local rivers and lakes as well as speeding up the natural process of soil depletion, causing many problems for farmers and their communities.

Soil depletion is the term for the loss of essential plant nutrients from the soil. This can occur for many reasons. The main cause of soil depletion is the loss of important elements in the soil such as phosphorous, nitrogen, and potassium. These elements are used by plants to make proteins which they need to grow. Another cause of soil depletion is the loss of minerals like zinc, manganese, and iron, which are used by plants to speed up their growth. Finally, soil depletion can occur when microorganisms such as bacteria in the soil die out.

One technique for preventing soil depletion is called crop rotation. Crop rotation is the practice of letting a plot of land recover its nutrients by not growing anything on it. Farmers leave alone a different plot of land in this way every year to prevent soil depletion.

Another simple but useful technology in farming is irrigation. Irrigation is the use of canals, sprinklers, and in-ground pipes to deliver water to crops. Because water is so important for plant growth, irrigation is a very useful and effective way of improving crop yield. Another benefit of irrigation is that once it has been set up, the benefits last for a long time with proper maintenance.

In recent years, a new technology for improving farming called genetic engineering has become popular. Genetic engineering alters the DNA of plants – it changes the genetic instructions used by the plants to grow. Because genetically modified (GM) plants are so new, it is unknown what effects they have on the environment. However, it is known that genetically modified crops tend to produce better yields, although they use up more nutrients.

GM crops can also cross-contaminate with organic crops, which can cause problems for small farms. Cross-contamination occurs when organic crops are pollinated by GM crops. This sometimes causes the plants to produce seeds which are sterile – unable to grow new plants. This can be a problem for small farms which cannot afford to buy seeds every year.

A big problem for the environment is the practice of "slashing and burning." This method involves cutting down a forest to use it as farmland. The problem with this method is that the soil from forests does not have the right nutrients for farming, and the soil is often very loose and tends to wash away when it rains. Not only does this hurt crop yields, it hurts the environment as well, because forests are a very important part of the ecosystem.

GAME RULES

STARTING THE GAME:

- Each student begins with an initial 10,000 Baht and two plots of land at the start of round 1.
- Each round has 3 phases:

1. **Purchase of Materials -** In phase 1, players may buy materials from the items list (below.) The limit is of 2 items per round, because of shipping limitations**.**

Items List

ORGANIC SEEDS

1000 baht

Roll on the Organic growth table for one plot of land. You may grow one organic crop next round without buying more seeds (you use the seeds from this crop) as long as you are not cross-contaminated and have enough plots of land.

GENETICALLY MODIFIED SEEDS

3000 baht

Roll on the GM growth table for one plot of land. Beware of cross-contamination – whenever you grow a GM crop together with organic crops, you must also roll on the cross-contamination table. Note that you must buy GM seeds *each round* in order to grow GM crops.

ORGANIC FERTILIZER

500 baht

+1 to your growth roll for one crop on the dice roll table for one round.

IRRIGATION

4000 baht

+1 to growth rolls for one plot of land for the rest of the game.

SILO

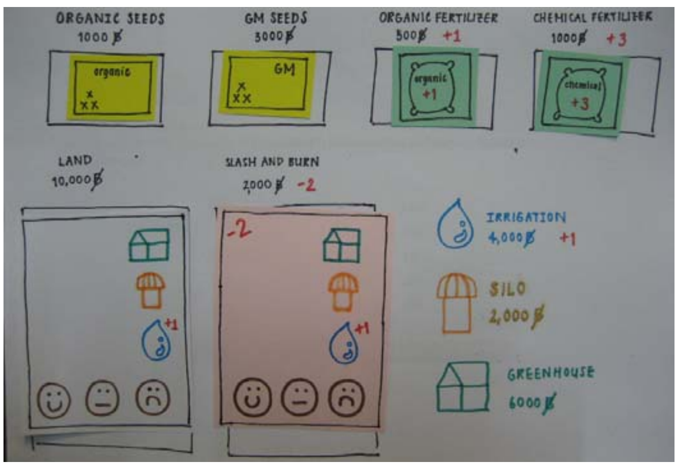
2000 baht

You may sell one extra crop per silo per round. This means that with one silo you can sell 3 crops per round, with 2 silos you can sell 4 and so on.

ADDITIONAL LAND

10000 baht

You may grow one extra crop per round (per plot of additional land) for the rest of the game. You may have a maximum of 5 plots of land.



ตัวอย่างการจัดวางสินค้าบนกระดานเกมไบโอเทค

2. **Growing Crops** - In phase 2, players roll dice to determine the success of their crop growing season, using the dice roll tables (below.)

Table 1: Organic Growth

Dice Roll	Result
1	There is a severe drought. You cannot sell the crop, and it doesn't produce seeds.
2	Your crop is eaten by insects. You cannot sell the crop, and it doesn't produce seeds.
3	You grow just enough to feed yourself. You don't make any money, but the crop produces seeds that you can use next round.
4	Your crop produces a minimal yield. You can sell the crop for 2000 baht.
5	Your crop produces an average yield. You can sell the crop for 3000 baht.
6	Your crop produces an above-average yield. You can sell the crop for 4000 baht.

Table 2: GM Growth

Dice Roll	Result
1	There is a severe drought. You cannot sell the crop.
2	Your crop produces minimal yield. You can sell the crop for 2000 baht.
3	Your crop produces an average yield. You can sell the crop for 3000 baht.
4	Your crop produces an above-average yield. You can sell the crop for 4000 baht.
5	Your crop produces an above-average yield. You can sell the crop for 4000 baht.
6	Bumper crop! You can sell the crop for 5000 baht.

3. **Selling crops and materials –** In phase 3, players redeem their crops for more money and may sell back any materials they don't want. The limit is of 1 item and up to 2 crops, due to shipping limitations. If players want to sell additional crops, they must buy a silo per additional crop to be sold. Any crops not sold are lost at the end of the round.

During the game

The cost of items sold back are always 50% of the original price during the game.

Ending the Game

- The game ends after 10 rounds.
- At the end of the game, add half the value of each of your other items - such as irrigation, greenhouses, and slash & burn land.
- The winner is the person with the most money added up.

Value of Items and Land at end game

Items/Land	Value (Baht)	Extra end game rules
Land	8000	Deduct 1000 baht for each soil depletion marker on the land.
Silos	2000	
Organic Seeds	2000	You can only sell 1 organic seed. Each additional silo allows the sale of 1 more organic seed.
Irrigation System	2000	

QUESTIONS

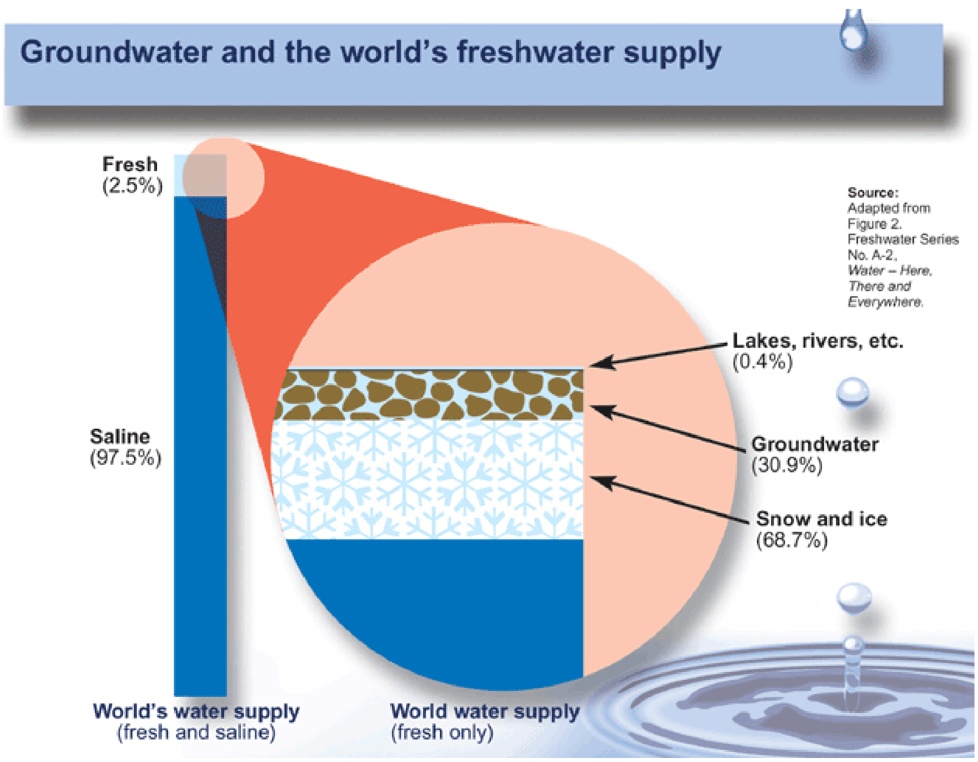
1. What was your strategy?
2. If the game had been longer, how would you have changed your strategy?
3. Who won the game? What was their strategy?
4. Based on the game, list the advantages or disadvantages of :
    a. Organic crops
    b. GM crops
    c. Organic fertilizer
    d. Irrigation
5. What was a good way to prevent soil from becoming depleted?
6. Was it worth investing in farm improvements such as irrigation?
7. What were some of the essential minerals for plant growth?
8. What were some of the essential nutrients for plant growth?
9. What has been changed in genetically modified crops?
10. Which is better for the environment, organic or chemical fertilizers? Why or why not?

Part 1: Groundwater Model

http://www.ec.gc.ca/water/en/nature/grdwtr/e_gdwtr.htm

BACKGROUND INFORMATION

Groundwater makes up 30.9% of the earth's fresh water supply. **Groundwater** is water that is under the surface of the earth. It is found between the spaces in rocks and soil. Many rural places rely on groundwater as its main source of water. That is why it is important to keep groundwater from being contaminated. It is unhealthy for people to drink the contaminated groundwater. Also, vegetables and fruits from farms that use contaminated groundwater can reduce crop yield and poison the people who eat the food. The chart below shows the percentages of the world's freshwater supply.



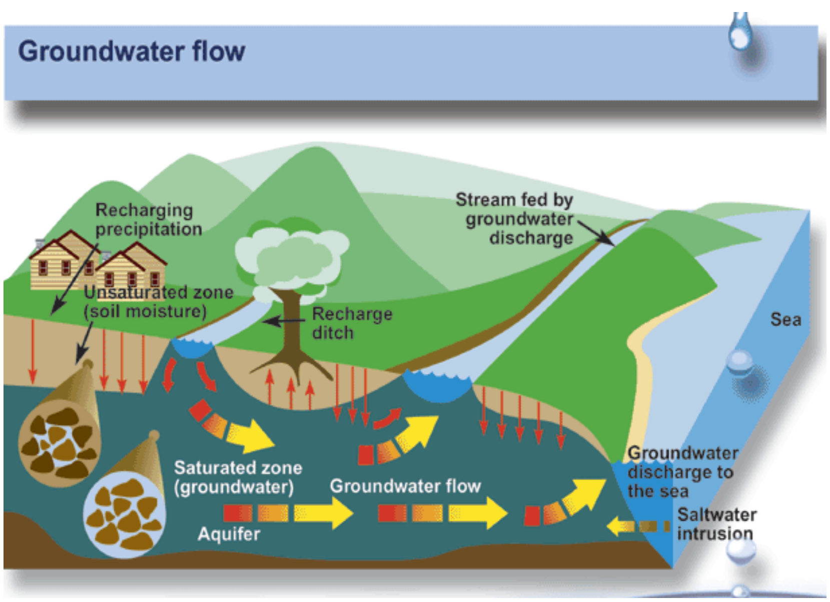
http://www.ec.gc.ca/water/en/nature/grdwtr/e_gdwtr.htm

So where is groundwater located exactly? In the soil there is something called the water table. This is an imaginary line that separates the unsaturated and saturated zones of the earth in a region. All the spaces below the water table are filled with water and are known as the **saturated**

zone. The **unsaturated zone** is where soil has a mixture of air and water between the spaces between rocks and soil. Groundwater is found in the region of earth called the saturated zone.

Permeable materials have cracks and pores that allow free movement of water. Certain materials are more permeable than others. This means that water flows through the material at a quicker pace. In some materials water can travel several meters in one day or a few centimeters in a century. Some materials hardly allow any water to flow through them and are known as impermeable materials. Clay and shale are two examples of Impermeable materials.

There are certain areas underground that produce more easily accessed water than others. These **aquifers** are made of lose material and/or permeable rock that can produce big amounts of water. When digging a well you are looking for an aquifer. There are two main types of aquifers. **Porous Media** are small particles of material such as gravel and sand. Porous Media can be found either in consolidated or unconsolidated form. In consolidated form the grains are fused together and in unconsolidated form the small particles are not connected together. Most well water supplies are from unconsolidated porous aquifers. **Fractured Aquifers** are aquifers that are composed of solid rocks where water flows in-between fractures and cracks. This can be composed of nonporous materials but because of cracks and fractures in the object water flows through it.



http://www.reachoutmichigan.org/funexperiments/quick/uiuc/h2oquality.html

MATERIALS LIST

- Sand
- Soil
- Rocks
- Medium and small gravel
- Water
- Food coloring
- A clear shoebox container
- 2 Plastic straws
- 200 mL Beaker
- Syringe

PROCEDURE

1. Pour big rocks on the bottom of the container so that the whole bottom is covered.
2. Place medium sized gravel on top of the rocks and level out smoothly then cover with small gravel and level.
3. Hold two straws vertically in place, inside the gravel.
4. Add a layer of sand above the gravel and leave some space for soil.
5. Cover sand with chosen amount of topsoil making sure to not over fill container. (Note: the ratio of soil to sand to rocks should be 1:1:4)
6. Slowly add water to the soil until the water reaches the top of the gravel and rock layer
7. Use syringe to draw water from the straws and observe what happens.
8. Slowly add 200ml of water with food coloring to the top of the model until you observe green water flowing into the rock layer.

9. Use a syringe to draw water from the two wells and observe how the contaminant moves through the water.

QUESTIONS

1. What did you observe when you drew water through the first straw? The second straw?
2. How did the contaminant move through the water before you sucked water up through the wells?
3. When you drew water from the second well how long did it take the contaminant to show up in the syringe? If the contaminant wasn't drawn through the water why do you think this happened?
4. Based on what you observed do you think it is important to be careful of what people put into the ground and explain why using your observations?

Part 2: Measuring pH in Native Water

http://www.hach.com/fmmimghach?/CODE:LG0045861|1//true

BACKGROUND INFORMATION

pH is a measure of how acidic or basic a solution is. The pH scale runs from 0-14 with below 7 to 0 being acidic and above 7 to 14 as basic solution 7 is neutral. Pure water has an ideal pH of 7. Rain water usually has a pH of around 5.6 so it is slightly acidic, but with pollution rain water can become acid rain, meaning its pH level is between 4.0 and 5.0. Below is a table of pH and some common substances that fall under each level.

Concentration of Hydrogen ions compared to distilled water		Examples of solutions at this pH
10,000,000	pH= 0	Battery acid, Strong Hydrofluoric Acid
1,000,000	pH = 1	Hydrochloric acid secreted by stomach lining
100,000	pH = 2	Lemon Juice, Gastric Acid Vineger
10,000	pH = 3	Grapefruit, Orange Juice, Soda
1,000	pH = 4	Acid rain Tomato Juice
100	pH = 5	Soft drinking water Black Coffee
10	pH = 6	Urine Saliva
1	pH = 7	"Pure" water
1/10	pH = 8	Sea water
1/100	pH = 9	Baking soda
1/1,000	pH = 10	Great Salt Lake Milk of Magnesia
1/10,000	pH = 11	Ammonia solution
1/100,000	pH = 12	Soapy water
1/1,000,000	pH =13	Bleaches Oven cleaner
1/10,000,000	pH = 14	Liquid drain cleaner

http://www.odec.ca/**p**rojects/2005/edgc5c0/public_html/phscale.gif

The pH scale is important to life on this planet. Most plants that humans rely on for food produce the highest yields based on being at certain pH level. Acid rain has a negative effect on crop growth because it makes the soil too acidic. The human body needs to maintain a pH of between 7.35 and 7.45. If the pH level is outside of this range it can be fatal.

pH testing is used in many important applications around the world, increasing crop yields, preventing milk from turning sour, and purifying water. One way of knowing if your groundwater is contaminated is if the pH of the groundwater is far from the neutral 7. Most groundwater supplies will not fall below 5, unless heavily contaminated. The closer your water is to a pH of 7 the safer it is to drink.

MATERIALS LIST

- Three 200 ml beakers
- Well water
- Pond Water
- Purified water
- pH paper

PROCEDURE

1. Fill 200 mL beaker with 100 mL of well water.
2. Test water pH with pH paper and record color change.
3. Look on pH scale for numerical value.
4. Repeat steps 1 – 3 for pond water and purified water.

OBSERVATIONS AND DATA COLLECTION

Water used	Color on pH indicator	pH value	Acid/Base

QUESTIONS

1. Of the three substances you tested which was the most acidic and give possible reasons for why.
2. What material was the least acidic?
3. Do you think it is good to drink heavily acidic or basic water?
4. Why may your groundwater not be perfectly neutral?

Optional Lab #1 : Permeability Lab

MATERIALS LIST

- Sand
- Soil
- Small Gravel
- Water
- Filter paper

- Three 200 mL Beaker
- Syringe
- Funnel

PROCEDURE

1. Fold the filter paper into quarters and open so it's a cone. Place cone filter paper into a funnel and place onto beaker.
2. Add gravel to the funnel so that it is half way full.
3. Repeat steps 1 and 2 for sand and soil.
4. Add 50ml water into the three funnel at the same time using the syringe and wait for one minute and observe the flow rate of water.
5. Measure amount of water in each beaker after one minute and record on table.

OBSERVATIONS AND DATA COLLECTION

	Volume of water (mm)	Permeability (rank)
Gravel		
Sand		
Soil		

QUESTIONS

1. What material was the most permeable and why?
2. What material was the least permeable and why?
3. What would happen if we added a fourth test with clay as a media?

Optional Lab #2 : pH Lab

MATERIALS LIST

- Lemon Juice
- 200 ml beakers
- Lye soap
- Water
- Table salt
- pH paper

PROCEDURE

1. Fill 200 mL beaker half way with water.
2. Place pH paper into water and record color change.
3. Look at pH scale and determine numerical pH value.
4. Empty beaker and refill halfway with water.
5. Add 50 mL lemon Juice.
6. Repeat steps 2-4.
7. Add packet of Table salt.
8. Repeat steps 2-4.
9. Add shavings of Lye soap to water.
10. Repeat steps 2 and 3 then clean beaker.

OBSERVATIONS AND DATA COLLECTION

Solutions	Color on pH indicator	pH value	Acid/Base
Water			
Lemon Juice			
Salt			
Liquid Soap			
Vinegar			

QUESTIONS

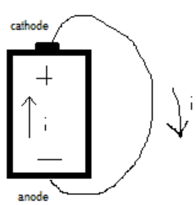
1. What material was a base and what was an acid?
2. Do you think the pH level would change if you added more lemon juice to the water?
3. How could you change your acidic solution to a neutral solution?
4. Was your water perfectly neutral? If it wasn't neutral what might be some reasons why?

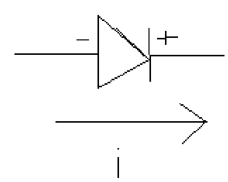
BATTERY LAB

BACKGROUND INFORMATION

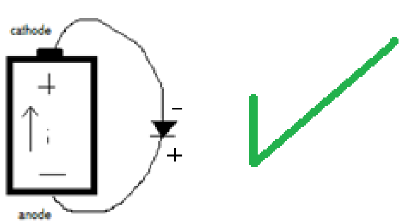
Batteries have three main components: a *cathode* (positive electrode), an *electrolyte*, and an *anode* (negative electrode). An electrode is usually a type of metal such as copper or zinc, and an electrolyte is a chemical such as lime juice or saltwater. Chemical reactions between the electrodes and the electrolyte cause a voltage to appear across the two electrodes. The cathode has a positive voltage with respect to the anode, which means current will flow through the battery from the anode to the cathode when a circuit is made.

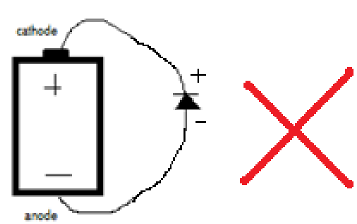
LEDs are a member of the family of electrical components called *diodes.* Diodes only allow a current to flow in one direction. Like batteries, diodes have a cathode and an anode and, like batteries, current flows from the anode to the cathode. Current *cannot flow* from the cathode to the anode of a diode. *Light-emitting diodes*, called LEDs for short, emit light when enough current flows through them. Because of the way diodes resist current flow, LEDs usually emit light when around *0.7 volts* are applied to them.





Current only flows when a circuit is made. In our circuit we had two components: the battery and the LED. When we connected the wires to the LED and the two ends of the battery, we completed the circuit and current could flow. However, if we connected the diode backwards, no current could flow.





Part 1: Lime Battery

MATERIALS LIST

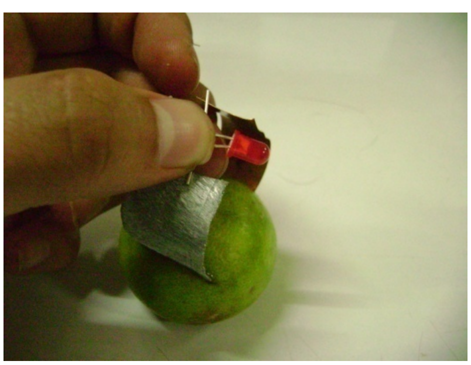
- Limes (4 Per Group)
- 4 Strips of Copper or Equivalent copper coins
- 4 Strips of Zinc or Galvanized Nails
- Aluminum Foil
- Tape
- light-emitting diodes (LEDs)

PROCEDURES

1. Place the copper strip/coin into one side of the lime.
2. Place the zinc strip/galvanized nail into the other side.

   Note: Make sure the zinc and copper do not touch inside the lime!!

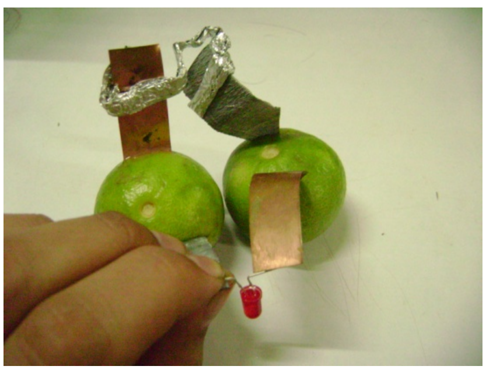
3. Attempt to light up a light-emitting diode by attaching the + side of the LED (the one with the longer wire) should be connected to a copper strip or coin, and the aluminum attached to the zinc to the – side.



4. Repeat steps 1-2 with the limes, so you have 4 lime batteries.

5. Connect the copper on one lime to the zinc on the other lime by using the aluminum foil to link them together. Use tape if necessary. Leave the limes at the end unconnected but with long strips of aluminum foil attached.

6. Now connect the two strips of aluminum foil to that of the LED. The + side of the LED (the one with the longer wire) should be connected to a copper strip or coin, and the aluminum attached to the zinc to the – side. Observe and record what happens.



7. Connect the LED backwards, so that copper goes to – and zinc to +. Observe and record what happens.

8. Remove the aluminum foil and metal pieces so you can use them in the next part of the experiment

Part 2: Salt Water Battery

MATERIALS LIST

- 4 x 50mL Beakers
- Water
- Salt
- 4 Strips of Copper or Equivalent copper coins
- 4 Strips of Zinc or Galvanized Nails
- Aluminum Foil
- Tape
- light-emitting diodes (LEDs)

PROCEDURES

1. Add water to the four 50mL beakers until they are almost covered.
2. Add a large amount of salt into the solution and stir.
3. Fold the metal strips into half.
4. Place the copper strip/coin onto one side of the beaker.
5. Place the zinc strip/galvanized nail into the other side.

   Note: Make sure the zinc and copper do not touch inside the beaker!!

6. Repeat steps 1-2 until you have 4 salt water batteries.
7. Connect the copper on one beaker to the zinc on the other beaker by using the aluminum foil to link them together. Use tape if necessary. Leave the beakers at the end unconnected but with long strips of aluminum foil attached.
8. Now connect the two strips of aluminum foil to that of the LED. The + side of the LED (the one with the longer wire) should be connected to a copper strip or coin, and the aluminum attached to the zinc to the – side. Observe and record what happens.

9. Connect the LED backwards, so that copper goes to – and zinc to +. Observe and record what happens.

QUESTIONS

1. In part 1, what material was the cathode made out of? What material was the anode? What was the electrolyte? What about in part 2?

   Hint: Electrolytes are usually a liquid chemical, and electrodes are usually metals.

2. Why did we have to use four lime batteries in series to light the LED? Did the lime batteries generate voltages on their own?

   Hint: Voltage is always generated when an electrolyte is placed between an anode and a cathode.

3. Based on your answer to question 2, what can you say about voltage sources (such as lemon batteries) in series?

4. In step 13, why didn't the LED light up?

   Hint: Was current flowing? Why or why not?

5. If you have three batteries which are 1.5 volts each, what do you have to do to get a voltage of 4.5 volts out of them?

   Hint: How should you connect them together?

ELECTRICAL SAFETY QUESTIONS

<table>
<tr>
<td>Formula Used:

V = I X R</td>
<td>Words to learn:
Voltage (V) = the difference of electrical potential between two points of an electrical or electronic circuit

Current (I) = Flow of electric charge
Resistance (R) = A measure of its opposition</td>
</tr>
<tr>
<td colspan="2">General knowledge:

Current of 1mA – You would experience a small shock or jolt

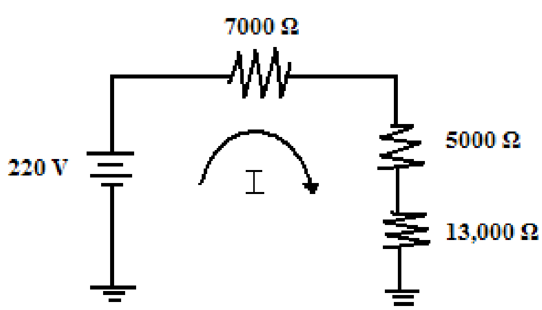
10 mA – You would be in pain and could become paralyzed

100 mA – Your heart could stop beating leading to death</td>
</tr>
</table>

EXAMPLE 1

Sean is trying to fix friend's computer. The voltage from the source is 220 V AC because the ground line wasn't checked and repaired. Sean decides to wear gloves which has a resistance of 5000 Ω and boots with resistance of 13000 Ω for safety reasons. If his body has an additional resistance of 7000 Ω, what would happen if Sean touches the computer while its plugged on?

1). Draw a circuit diagram representing the situation:

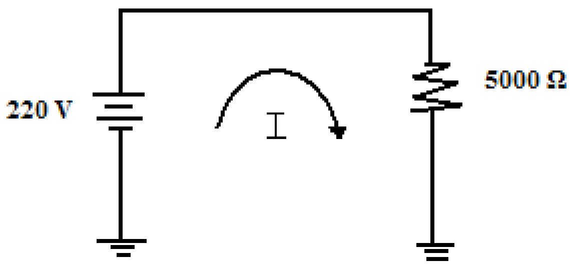


2). Calculate the current (I)

$$\frac{220\ V}{25000\ \Omega} = 8.8\ mA$$

3). Is it possible that Sean will lose his life? How much pain do you think he is in?

4). If Sean did not wear gloves and boots, would the electricity flow through his body? What level of pain would he be in?



$\frac{220\ V}{5000\ \Omega}$ = 44 mA Very Painful

QUESTIONS

Elias is repairing his house. While hammering a nail into the wall, the nail hit an electrical cord. Since he was palms were sweaty, his body resistance was decreased to 2000 Ω. The hammer had a resistance of 1000 Ω

1). Draw a circuit diagram representing the situation:

2). Calculate the current (I):

3). Would Elias die from this situation? How hurt would he be?

4). What should Elias do to improve his chances of survival?

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