Nutrition and Nitrogen Cycle Instruction in Timor Using A STEM Approach with Aquaponics

by

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Field Project

Submitted in partial fulfillment of the requirements for the

Master of Science Degree in Education

Graduate Studies

Martin Luther College

New Ulm, MN

March 2017

Signature Page

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Abstract

The following document details a field project conducted in a small Lutheran school in Timor, in rural Indonesia. One purpose of this study was to support teachers and instruct students about nutrition and the nitrogen cycle through aquaponics. This project focused on the challenges and hopes of teaching in a remote area of Indonesia, using accessible materials and introducing STEM education. The people involved in this study were the administration, teachers, students, and parents of Grace Lutheran School, Kupang. In addition, several other people were involved in the organization, teaching, and translating of materials.

Recognizing the needs of children and educators alike, Gereja Lutheran Indonesia and Kingdom Workers have been committed to improving education and supporting spiritual growth in their schools. In addition, they have recognized the importance of promoting sustainable development. This goal of this project was in line with those commitments. Four teachers and 31 students were introduced to a new way of teaching and learning that, with continued support, will help to shape the future of their school and their lives.

Acknowledgments

I would first like to acknowledge the participants of this study, especially the teachers of Grace Lutheran school (Ibu Fitri, Ibu Mince, Ibu Marlince and Ibu Meri), for trusting me and being willing to step outside of their comfort zone to approach something very new.

I would like to thank two other Indonesian women, Ibu Ester and Ibu Dewi. Without their help, this project would not have been possible. Ibu Ester, the director of Multi-Language Publications Indonesia, spent many hours translating documents and materials and Ibu Dewi provided direction by instructing the teacher and students.

I would like to thank Kingdom Workers for seeing the value in pursuing a master's degree and supporting me with the time and financial support to move forward.

I would also like to acknowledge my committee chair, Dr. John Meyer, for his guidance and support along this journey. In addition, my committee members, Dr. Paul Boehlke, who greatly inspired me, and Dr. David Wendler, who added expertise.

Finally, I give thanks to God, who deserves all the glory for providing me with supportive people around me and the motivation to finish this work.

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Chapter I: Introduction

Identify the Issue

In July of 2014, I began a new job with Kingdom Workers as the Southeast Asia Health and Education Coordinator. My twenty-nine years of teaching experience provided a natural connection to many of the education issues facing Indonesian teachers, students and schools. Health issues, on the other hand, were something fairly new to me. Many of the health topics that need to be addressed, like personal hygiene and dental health, are what Americans might consider common sense issues. Others, like access to clean drinking water and malnutrition, however, are much more complex. What soon became very clear was that both health and education issues are often intertwined and problems and solutions for one related to the other.

Kingdom Workers uses a Participatory Learning and Action approach (PLA) to address the steps that lead to community development (Kenton, 2016). This type of approach is often used in rural communities of developing countries and has proven to be effective because it taps into the unique perspectives of those in poverty, helping to unlock their ideas and find realistic solutions (Thomas, n.d.). It is the active engagement of people in decision-making processes, which encourages and empowers all community members to participate and take greater ownership and responsibility on issues that affect their lives (Kenton, 2016).

In an effort to make a long-term difference for the people of Kupang, Nusa Tenggara Timor, in eastern Indonesia, there is a need to work on a more comprehensive approach that addresses health issues in schools. If children can be educated from a young age about health and health-related issues, there is a better chance of effecting change. In addition, if this education can be meaningful in that it can make connections to the everyday lives of the people, it will serve an even deeper purpose. Science, Technology, Engineering, and Math (STEM) education, an integrated and hands-on approach in the United States, may be a useful educational approach to accomplish those meaningful connections for the children of Kupang, Nusa Tenggara Timor.

STEM education has become very popular. The combination of the several fields is attractive and tends to motivate students. Furthermore, it is easy and natural to add the arts (communication and drawing) as many suggest and make the situation STEAM. Good STEM/STEAM education requires hands-on experiences and the development of problem solving skills. A challenge, however, when teaching in countries with few resources and educational materials, is how to accomplish this. Aquaponics proved a useful tool to address that challenge.

Importance of the Project

On the island of Nusa Tenggara Timor (NTT) there is growing recognition that school gardens and aquaponics can help fight malnutrition and undernourishment. Django Van Tholen (2015) reported that children are among the most vulnerable members in Timorese society: 58% suffer chronic malnutrition; 38% suffer from anemia, malaria, diarrhea and other diseases; and most children do not reach their ideal weight. The opportunity to provide meals to children from school gardens and to further educate students in food production and good nutrition is being promoted and supported by many non-government organizations (NGOs) around the world. The thinking is to put emphasis on the understanding of nutrition into the national curriculum. Aquaponics, especially as an educational tool, is seen as being one part of the total picture (Van Tholen, 2015).

Kingdom Workers, a para-synodical organization of the Wisconsin Evangelical Synod, is a type of non-government organization that has also identified aquaponics as a tool for evangelism and health involving food for both body and soul in other areas of the world and is even now pursuing using it in NTT with Grace Elementary School students and the wider Lutheran Church of Indonesia.

Project Purpose

The purpose of this study was to teach children to use the study of aquaponics, with a hands-on, STEM education approach, to gain a greater understanding of the nitrogen cycle and the possible effects on health and nutrition. While learning how to set up an aquaponics system and the biochemistry of proteins and nitrogen, the children used problem solving skills to determine if and how plants and fish would grow and prosper together in this symbiotic system. The project included the use of readily available, inexpensive, and innovative aquaponics technology on the island of Nusa Tenggara Timor. The intention was that with these resources, meaningful, relevant education for the children would be fostered. This method of teaching was completely new to the teachers and students of NTT, so it was very important to work alongside teachers to implement this project.

Chapter II: Literature Review

Background

Sane (1999), writing for The World Bank, noted that the developed world recognizes the importance of science and technology to improve the quality of life and therefore gives the teaching of both a high priority. In the United States alone, more than $250 million, through public and private funding, has been allocated to prepare new and existing math and science teachers (The White House, 2010). President Barack Obama (U.S. Department of Education, 2015) stated,

> [Science] is more than a school subject, or the periodic table, or the properties of waves. It is an approach to the world, a critical way to understand and explore and engage with the world, and then have the capacity to change that world..." (U.S. Department of Education, 2015).

Developing countries, however, often continue to hold on to an education system that is ill-suited to the needs of a fast-changing world. Rather than emphasizing the need to acquire skills, these countries are often driven by the need to pass memory-testing examinations, (The World Bank & Sane, 1999). Sane (1999) contended that in order to develop science and technology skills, a hands-on approach is needed. This type of a hands-on approach can be prohibitive to those who lack funds to purchase equipment and train teachers. Since there is a lack of funds in developing countries, it is therefore crucial that governments, non-governments organizations, and the local schools work together to develop reliable, locally produced, low-cost equipment with simultaneous support for teachers through workshops and training (p.129).

Challenges

There are a number of obstacles with glimpses of hope for education in Indonesia. Funds are needed to build up educational systems in developing countries like Indonesia, and many countries devote a good portion of their budgets to supporting education. Concerns about corruption often accompany any type of project in this country. According to Transparency International (2014) the Corruption Perceptions Index ranks Indonesia 88 out of 168 countries or territories being measured. A country or territory’s score indicates the perceived level of public sector corruption on a scale of 0 (highly corrupt) to 100 (very clean). A country's rank indicates its position relative to the other countries in the index. It is interesting to note that Indonesia has moved up on the scale over the last few years, so there is recognition of some improvement in the way the government is handling its funds.

The World Bank (2014) reported that the Indonesian government has significantly increased the amount of money being put into education recently – reaching more than 16% of its total government expenditures, making it comparable with similar countries with 3.4% of the GPD being allocated to education. There are vast differences in education, however, in regard to school enrollment in urban and rural areas of Indonesia. Enrollment is nearly 100% in urban areas but less than 60% in rural elementary schools. Remote areas tend to be the poorest, and children in these areas, the most disadvantaged (The World Bank, 2014). United Nations Educational, Scientific and Cultural Organization (UNESCO) (2016) also reported that children are less likely to attend school if they live in rural areas, are poor, or have parents with little or no education. Classroom observations done in a number of urban and rural Indonesian schools by

Wayhudi (2006) showed that students in the rural schools were not nearly as positive about school or science instruction as their counterparts in urban areas because of a lack of materials, books and activities (p. 243).

An inequitable distribution of teachers as well as funds in rural and remote schools exists. The teacher qualification levels also reinforce this inequality (The World Bank, 2014). Both the quality and quantity of instruction is a common concern in developing countries like Indonesia. Shortages of teachers and facilities often result in double shifts that end up shortening the school day for children. With weak incentives and little supervision, teacher absenteeism runs high in many schools. Beyond absences, teachers who are present are often not actually teaching (Glewwe, 2006).

Supporting teachers with professional development can bring about positive change. A study shared in an article by The World Bank & Warren Beasley (1999) showed the importance of improving teacher competencies through in-service training. Two hundred and forty-three teachers from five different regions of the Philippines recognized in-service training that includes hands-on operations, teaching strategies and the preparation of materials, lesson plans and assessment instruments to be of specific concern and importance (p. 158).

STEM

What is STEM or STEM education? While many agree there is a need to push science, technology, engineering and mathematics in schools to encourage children to think about future jobs within those disciplines, there is not always agreement on what STEM education actually is and how it should be carried out within schools. For the purposes of this study, the following operational definition of STEM by Vasquez, Sneider, and Comer (2013) will be used:

> STEM education is an interdisciplinary approach to learning that removes the traditional barriers separating the four disciplines of science, technology, engineering, and mathematics and integrates them into real-world, rigorous, and relevant learning experiences for students. (p. 4)

According to Merrill (2009), STEM teaching and learning also focuses on innovative ways to help solve human wants and needs. Integrative STEM education is grounded in the tenets of constructivism and the findings of three decades of cognitive science. Bruning, Schraw, Norby, and Ronning (2004) identified the following set of cognitive themes that resonate with integrative STEM education:

- Learning is a constructive, not a receptive, process.
- Motivation and beliefs are integral to cognition.
- Social interaction is fundamental to cognitive development.

As recorded by Holbrook (2009) a school curriculum should include three general educational aims:

- Acquisition of knowledge, skills, abilities or capacities.
- Development of competencies, i.e. the ability to apply the knowledge and skills imparted by education to real-life situations.
- Development of key competencies, i.e. those that are essential in order to participate effectively within society.

Those who support STEM education feel that it can lead to improved problem-solving skills, analytical and critical thinking skills as well as lead to better real-world connections in the curriculum (Brown, Brown, Reardon, & Merrill, 2011).

There is also a great deal of research being done in terms of using STEM education to promote sustainability. According to the World Commission on Environment and Development (1987) sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Towards Sustainable Development section, para. 1). With sustainable development in mind, Holbrook (2009) considered how science and technology education could be used so that it leads to true sustainability and, in addition, suggested what role NGOs can have in promoting and enhancing self-empowerment, equity, and fairness in developing science literacy for those in developing countries. Holbrook and Rannikmae (1997) defined scientific literacy to mean: "develop the ability to creatively utilise sound science knowledge in everyday life, or in a career, to solve problems, make decisions and hence improve the quality of life" (p. 15).

Aquaponics

STEM education can be implemented through the study of aquaponics. Aquaponics is the cultivation of fish and plants together in a constructed, recirculation ecosystem utilizing natural bacterial cycles to convert fish waste to plant nutrients (Bernstein, 2011). It is an organic system in which nutrients are naturally balanced. Since it is a closed, recirculating system it uses less than a tenth the amount of water than do traditional farming methods (Bernstein, 2011), an area of concern in a place like Kupang where water is not easily accessed.

Aquaponics in education is of growing interest as noted by the many articles, books and lesson plans available on the Internet. The interest can be explained for many reasons. One reason is because of the range of related topics that may make aquaponics an effective tool for STEM education by making connections across the four disciplines of science, technology, engineering and mathematics. It also requires hands-on, experiential and integrated learning with connections to food security, agriculture, sustainability, economics, business, and health (Hart, 2013).

The scope of this field project, while small in comparison to others, is not the only one of its kind being done in Timor. Timor Leste is now a sovereign nation but was once part of Indonesia. This independent country shares a border with Nusa Tenggara Timor and faces the same challenges – lack of access to clean water, malnutrition and poor economics and educational systems. Several non-government organizations are teaming up to promote health and economic success by forming an aquaponics and community garden project. Django (2015) stated that three broad initiatives are driving their project: 1) increasing accessibility to food and providing sustainable food production; 2) educating and increasing community capacity in sustainable farming techniques; and 3) bolstering food security through access to aquaculture for school meals.

The initiatives driving the project in Timor Leste, will be part of what drives this field project in Kupang. In addition, the training of teachers, so that they can lead these types of lessons in the future is of great importance. Fuller (1986) suggested that an important determinant of school quality is the behavior and quality of the teachers and school administration (p. 15). Important inputs include the use of instructional time, standards, and expectations for students, and teachers' ability to motivate young learners, (Fuller, 1986).

One must also consider the limits that exist within this school. There are very limited funds and resources. Like many other schools in developing countries, Grace Lutheran Elementary School lacks the most basic equipment and school supplies – textbooks, blackboards/whiteboards, desks, and benches or chairs.

It is useful to prepare activities that increase children's interest and motivation towards science, activities that they can relate to their daily lives and activities that can enable them to form learning experiences they can transfer to new situations, (Sener, Türk, & Tas, 2015).

Scriptural Integration

Having a foundational understanding of what science is, why and how it should be taught is of utmost importance for students and teachers alike. Teachers must recognize science as a human endeavor through which God blesses us. It is to be highly valued as such and used to carry out stewardship of the earth's resources (Boehlke, Klockziem & Paulsen, 1997). Stewardship of God's creation needs to be taught by helping children to understand as much as possible about how creation works. When this is done, teachers and students are compelled to learn more science. Promoting guided discovery, asking the "why" questions, and using problem solving activities are just some of the strategies teachers can employ to facilitate meaningful, transferable lessons from an explicit Scriptural viewpoint (Boehlke et.al., 1997).

Chapter III: Implementation

Introduction

The purpose of this study was to teach children to use the study of aquaponics, with a hands-on, STEM education approach, to gain a greater understanding of the nitrogen cycle and the possible effects on health and nutrition. With few resources and and limited access to materials, it was a challenge, yet, aquaponics proved a useful tool to address the challenge.

Procedures

In developing this field study, the author of this paper first discussed with the pastor, the acting principal of Grace Lutheran School at the time, about the feasibility of this project. He was excited and willing for the teachers, students, and parents to be involved. The teachers also expressed interest in participating as they welcomed the chance to grow as educators. An Indonesian education expert, a recent hire of Kingdom Workers, was asked to assist in the development of the unit, the training of the teachers, and the teaching of the students. This was done so the author of this paper would be sure the material was culturally and academically appropriate for the Grace Elementary students and presented well in the mother tongue of all the participants.

At the same time, sample aquaponics lessons and activities that were based on STEM education and would be fitting for students in Kupang, Indonesia were compiled. Help was asked from the Multi-Language Publications director for Indonesia to work on translating the lessons as well as all other pertinent materials, including the original proposal written for this field study. After translation was finished, the Indonesian expert teacher and the author of this paper made decisions on how best to proceed with the project.

To gain permission from parents, letters were sent home to parents, introducing the project. Parents were to indicate whether their child could participate. Several parents required home visits because either they did not return the letter, or they were unable to read or understand the scope of the project. In the end, all the parents consented to let their child or children join.

Prior to concepts being introduced or lesson plans being set, attitudinal surveys were written, translated and given to both teachers and students (Appendix B). The goal for the teacher survey was to gather information that showed what they felt about science in the past as students and now as teachers; how much they enjoyed learning science and how much they enjoy and value teaching it. Regarding the students, information was gathered to find out how students felt about learning science and what interested them. Both teachers and students were asked about their prior understanding of STEM education.

Within the scope of using STEM education and together with the teachers of Grace Lutheran School, six main lessons (Appendix A) with various objectives were designed around aquaponics understandings, and taught in the mother tongue of the students and teachers – Bahasa Indonesia. The teachers helped to organize formative assessments and design a rubric (Appendix D) that was used to record student progress and achievement at the end of the unit.

Participants

Participants in this field study were the students and teachers from Grace Lutheran School in Kupang, Nusa Tenggara Timor. Four teachers in the school participated along with the third and fourth grade students. The teachers were involved in the development of lesson plans. They were thoroughly discussed and explained. The local teachers themselves, along with the Indonesian expert teacher, employed by Kingdom Workers to help in the training of teachers, taught the lessons while observations were made and recorded (Appendix C) by the author of this paper. This was set up this way so that language differences would be less of an issue since the author has limited use of Bahasa Indonesia.

All the teachers were female and ranged in age from 31 to 44. One of the teachers has a bachelor’s degree from a local university while the other 3 have a high school diploma. Of the 31 students, 19 were boys and 12 were girls. Seventeen of the students were third graders while 14 were fourth graders.

The parents of the students who joined in this study signed permission letters indicating their willingness to let their children participate. Thirty-one students (100%) were granted permission from parents to participate but three different students were absent one day each over the course of the teaching and assessing days.

Other partners in this field study included a representative of MLP and a member of the Education Committee of the Lutheran Church of Indonesia.

Methods

Data. Several types of data were collected to measure the various aspects of this field project. A survey (Appendix B) was given to the teachers before the instructional unit (pre) and after the unit (post). This survey measured the attitude of teachers toward the learning and teaching of science, what they liked and found challenging, and how well they are able to integrate Scripture into the subject matter. In addition, teachers were asked what they knew about STEM education.

The students also completed a survey before the instructional unit and after. This survey measured the students' attitude toward the learning of science, what they liked and found challenging, and how important the learning of science is to their everyday lives. The students were also asked if they understood the meaning of STEM education.

Data was collected from students in the form of observations and assessments. Formative assessments were given over the course of the project. They included an attendance and participation checklist, activity sheets, worksheets, math work and writing activities.

Attendance each day was tracked using a checklist. To evaluate participation, a tally mark was made by the name of each student as they interacted in their group during a lesson. Each teacher was responsible for one or two tables of students and when a child had a meaningful interaction with another student or a teacher, he or he was given a tally mark. Asking or answering a pertinent question, adding information or expanding on a point were some of the examples of what could have been counted as a meaningful interaction. Activity sheets and worksheets had children drawing and labeling the parts of a fish and the aquaponics cycle and recording what was learned in lessons. Connecting with math, groups of students had various tasks such as estimating and measuring how much water the fish tank would hold, calculating how many pieces of fish food were given over the course of the unit and beyond, estimating how long before the fish food container would be empty, measuring the height of the plants growing in the aquaponics bed as they grew each day, and figuring how much it would cost if a new container of fish food had to be purchased each month. For homework, each student kept a journal as a writing activity, gave the fish a name and wrote about what was learned that day from the perspective of the fish.

At the completion of the lessons, a summative assessment (Appendix D) was administered measuring two main outcomes: 1) explaining the nitrogen cycle in an aquaponics system, and 2) stating the possible health benefits from an aquaponics system. The task for the first outcome was to draw an aquaponics system and then explain the nitrogen cycle using their drawing. The second task was an oral explanation of how aquaponics could have health benefits for them. The tool used to record results of the summative assessment was a rubric (Appendix D). Several students were video-recorded giving their presentations and sharing their knowledge.

Analysis. Four teachers took the seven-question attitudinal survey both before and after the teaching unit. Four of the questions asked teachers about their levels of confidence using a scale of 1 (low) to 5 (high). The teacher ratings were averaged for comparison between pre- and post- unit attitudes. The results are shown in table 1.

Table 1

Teacher Self-Reported Science Attitudes

	Mean Score 1 = low; 5 = high	
	Pre	Post
Rate your interest to learn science as a child.	3	3
Rate your interest in teaching science to students in your classes.	4.5	5
Rate the interest level of your students to learn science.	3	4.5
Rate your confidence level in properly integrating Scripture into the teaching of science.	3.5	4.5

Note. Teachers completed a survey before (pre) and after (post) teaching the aquaponics unit indicating their perceived levels of interest and confidence in teaching science.

There were three open ended questions that asked the teachers what they liked and found challenging about teaching science and their knowledge of STEM education. It appeared that all four teachers misunderstood the question asking what they liked about teaching science. Their answers did not relate to the question properly. Perhaps this misunderstanding happened because the survey was not translated or explained properly. Three of the four seemed to also misunderstand the question asking what are the challenges to teaching science in both surveys. The fourth teacher indicated that the greatest challenge to teaching science was keeping the attention of the students. When asked in the pre-survey if the teachers were aware of what STEM education was, none of them had ever heard of the term. In the post-survey, all the teachers could tell what the letters STEM stood for and two answered in greater detail. One teacher shared that STEM education was more hands-on and active, while another shared that STEM education was more meaningful and interesting to the students.

Thirty-one students answered six survey questions before and after instruction (Appendix B) with the same rating scale. This attitudinal survey was designed to measure the attitudes of all participants toward science before and after this experience. When asked to rate their 1) interest in learning science and, 2) the importance of learning science, twenty-nine of the students (93.5%) rated both answers high in both pre- and post-surveys. Two students (6.5%) rated both medium to medium-low in the pre-survey but changed both ratings to high in the post-survey. When asked what they liked and what was challenging about learning science, the answers varied little. Answers ranged from animals to humans to nature in both categories. Students had no knowledge of STEM education in the pre-survey. In the post-survey, however, all but one of the students (nearly 97%) could recall the meaning of each of the letters in STEM. Five students shared that STEM education used experiments, three others added STEM education was more interesting or fun and one student said STEM was a new way of learning many subjects put together.

Attendance and participation were measured using a checklist. Of the thirty-one students, only three missed one day each, showing that all students achieved 90% attendance or higher. Participation showed improvement with 100% of the students engaged by lesson seven (see table 3 in Appendix E).

Formative tasks in this project included: a worksheet on the anatomy of a fish, a worksheet labeling and explaining the nitrogen cycle in an aquaponics system, math activity sheets, and a reflective writing piece. Most of the formative tasks in this unit were done within school hours and were worked on in group settings. Students were able to collaborate with one another and their teachers during lessons. The writing task was done as an assignment to be completed at home and was used the following day to review with their group members before beginning a new lesson. All formative tasks were rated as either complete or incomplete. When a student was absent, group members or a teacher worked with that individual to finish the task that was worked on the previous lesson. All thirty-one students (100%) completed each in-school task. The writing activity was assigned as homework and in order to achieve a mark of complete, a student had to have finished the work a minimum of six of the seven days. Twenty-two of the thirty-one students (70.97%) were successful with that task.

A rubric was used to record the results of the summative assessment (Appendix D). The results were labeled as highly competent, competent, developing and not yet evident and ranged from a high score of 3 being highly competent to a low of 0 being not yet evident.

Task one on the summative assessment was done by each student independently and then orally explained to one of two teachers so that the results could be recorded. For this task, the student created a drawing and used it to explain how an aquaponics system works. The average score for the thirty-one students for task one was 1.9 – a score just below competent.

In the second task, the students were asked to explain the possible health benefits of aquaponics. Two other teachers recorded those results on the rubric. The average score for task two was 2.23 - reaching competent. Several students were video-recorded sharing their answers.

From there the teachers divided into groups of two with guidance from the Indonesian expert teacher and the author of this paper to discuss the rubric and add comments. Finally, the four teachers each took one student at a time to share and explain the results on the rubric.

Table 2

Aggregated Summative Assessment Results

	Achievement Ratings - Number of Students			
	Highly Competent	Competent	Developing	Not Yet Evident
Task 1	3	22	6	0
Task 2	9	20	2	0

Chapter IV: Reflective Essay

Introduction

The purpose of this study was to teach children to use the study of aquaponics, with a hands-on, STEM education approach, to gain a greater understanding of the nitrogen cycle and the possible effects on health and nutrition. To that end, this study worked with teachers in Nusa Tenggara Timor – introducing them to new ways to teach; and with students – instructing them in ways different from the traditional methods used by their teachers. The students and teachers enjoyed using a STEM approach to education where materials were accessible and the learning was relevant and engaging.

Conclusions

STEM education was a completely new concept to students in Grace Elementary School, Kupang. The teachers acknowledged that the separate disciplines have not been adequately taught nor have the combination of disciplines been explored educationally prior to this project.

The first purpose of this project was to use engaging, hands-on lessons with an educational STEM approach to teach a unit on aquaponics. The students of Grace Elementary were exposed to STEM education for the first time through this field project. After several lessons with interdisciplinary connections, experiments, and hands-on activities, nearly 97% of the students were able to recall the meaning of the letters in STEM. The students were explicitly reminded during related math, science and writing lessons that what was being done was a part of the STEM education approach.

Another purpose for this project was to help the students at Grace gain a greater understanding of the nitrogen cycle through the study of aquaponics. In the first task of the summative assessment, students were to use their drawings of an aquaponics system to explain the nitrogen cycle. Eighty percent of the students received scores of competent or above, showing that those students were able to explain how the nitrogen cycle worked in an aquaponics system with a minimum of 75% accuracy.

The final purpose for this field project was to help the students to gain an understanding of the nutrition and possible health benefits that can come from the output of an aquaponics system. In task two of the summative assessment, the children were to give an oral explanation of this knowledge. Twenty-nine out of the 31 participants scored competent or above with 64.5% of the students achieving competent and 29% highly competent.

In addition to the intended purposes, other noteworthy conclusions could be drawn. Student attendance and participation in the unit indicate that this type of learning interested the students, causing a higher than usual rate of attendance. In contrast to the previous week where eight students were absent one or more days, student attendance was considerably higher, with a 90% attendance rate for the duration of the aquaponics unit. Participation was also high during class time as was evidenced by the increased amount of meaningful interactions reaching 100% by the end of the unit.

Another conclusion that could be drawn, although not a focus of this paper, was the benefit to the teachers. Through the teaching of this aquaponics unit, the Grace teachers learned new teaching techniques and strategies that can be applied in other classroom situations. With guidance in unit planning, they found ways to incorporate God’s Word so that the students could have greater appreciation for God’s creation and their role and responsibilities in it. They also understood what STEM education means and with the knowledge and continued training and support, they expressed a desire to find more ways to tie in God's Word, engage their students, and lead them in meaningful learning experiences that cross the different disciplines. The teachers also benefitted by being a part of the entire process from lesson planning, teaching and assessing their students. The author of this paper believes this group of teachers understands the benefit of STEM education and will do their best to find more ways to incorporate it with their students.

Recommendations

With the purpose of this project in mind, the author of this paper has specific recommendations. The first recommendation is for the students of Grace Elementary school to continue STEM education experiences. According to Morrison (2006) the benefits of STEM education include making students better problem solvers, innovators, inventors, self-reliant, logical thinkers and technologically literate (p. 2, 3). It is also recommended that STEM education with a focus on hands-on, active, problem-solving, relevant lessons, be fostered and encouraged, with the hope that the learning can be meaningful, sustainable, and help to improve the quality of life for our Kupang students.

The second recommendation is for scientific knowledge, such as the understanding of the nitrogen cycle, be taught in an integrated manner where an interdisciplinary curriculum "provides opportunities for more relevant, less fragmented, and more stimulating experiences for students," (Furner & Kumar, 2007; p. 186). Using an aquaponics system to teach the nitrogen cycle allowed the students to learn about the nitrogen cycle in a relevant and meaningful way. Providing integrated, purposeful learning opportunities like this in the future will help these students experience education in a more meaningful way and help them to be better prepared for the future.

The final recommendation, as it pertains to the purpose of this paper, is for continued education that looks at the health and nutrition needs of the children in Kupang and integrating it into units when appropriate. Within the lessons, children were able to see direct connections between the aquaponics system and health benefits that could be possible. It was this study's intent that, through integrating health education into the aquaponics lessons, children would become more knowledgeable about nutrition, be able to make wiser decisions for their personal health, and that in turn, school attendance as well as student achievement would improve.

Additional recommendations that extend beyond the project purpose include teacher training opportunities and enhancing materials and resources in the classrooms. Because the ideas of STEM education are new, steps that are manageable must be taken. A lack of materials and resources will make it important to move forward with an integrated approach that is sensitive to the skills and confidence levels of the teachers. Meyrick (2011) acknowledges traditional teaching methods will not support STEM instruction. Improving teaching skills is a process for all teachers. For some, there is little to no access to professional development. Kingdom Workers, alongside Gereja Lutheran Indonesia (GLI), should continue taking steps to provide professional development for teachers in remote areas of Indonesia where little attention has been given before. When something new, like STEM education, is introduced to teachers and students, continued training and support must be given to ensure success. It is, therefore, the recommendation of the author of this paper that Kingdom Workers, in partnership with GLI, continue to walk alongside the Kupang school community to hold teacher workshops, increase materials and resources, introduce and reinforce skills, model good teaching techniques and provide meaningful learning experiences.

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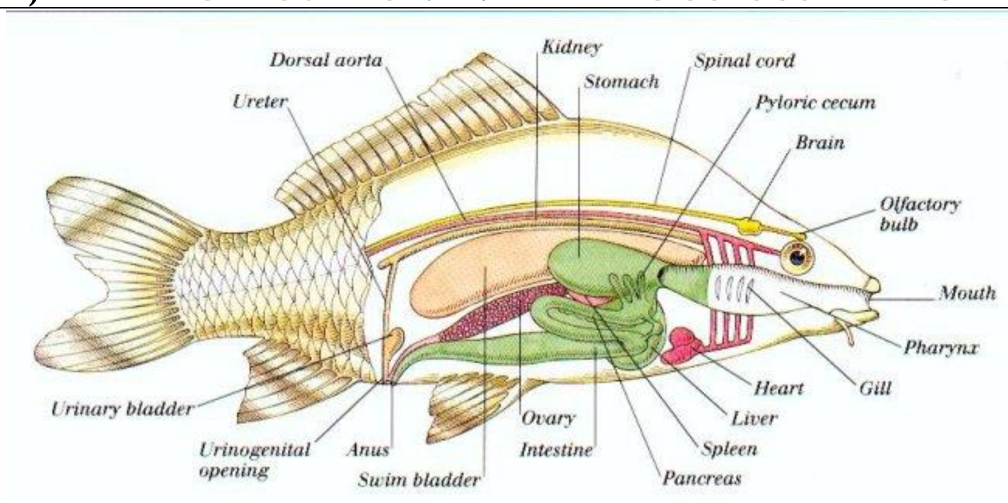
Appendix A: Lesson Plan Outline/Activities

The outline below includes the main objectives that were taught by the teachers and learned by the students. The teachers and the author of this study used the outline to further develop lessons and activities for the students. Careful consideration was given to be sure to include inquiry/guided inquiry and hands-on activities. The teachers, having learned about STEM education, identified the science, technology, engineering and mathematics components within this unit and saw how they can all be taught in an integrated manner. Lessons were translated into Bahasa Indonesia for classroom use.

Lesson 1) LEARNING ABOUT FISH: EVERYTHING GOES SOMEPLACE



The Digestive System of a Fish
Credit for image: Used by permission - Sharon High School. Wikimedia.

Objective 1: Understanding how food goes through a fish and is used.
Food travels through the fish from mouth to the stomach, then the intestines and then what is not used comes out through the anus. The food is digested and becomes part of the fish. Fish use food to make proteins for their muscles and other body parts. They are also an excellent source of food for humans. We can use the proteins to make our muscles, skin, and other parts. (Oils in fish meat are also vital for brain development.)

Objective 2: Understanding what happens when protein in an organism wears out.
Proteins have nitrogen in their structure. As protein breaks down ammonia is produced containing the nitrogen. (The teacher can illustrate by taking apart an object.)

Proteins (have nitrogen in them) → ammonia (has the nitrogen)

Waste including ammonia leaves the fish through the anus, the urinogenital opening, and the gills. Ammonia is toxic and cannot stay in large amounts in or around living things. Protein breakdown in living things makes ammonia, which contains nitrogen.
(Activity- Can put some ammonia on a plant and observe the toxic effect.)

Fish also need oxygen like we do. They get it from the water using their gills. Things move naturally from high concentration to lower concentrations. The oxygen in the water moves naturally into the fish gills, which have lots of surface. Ammonia that increases in the fish moves out into the water from high concentration to lower concentration.
(Can put some food coloring into water to show how it spreads from high concentration to lower concentration.)

(Option: If you put a drop of food coloring in front of a fish, it will shoot through the gills. The food coloring will not harm the fish.)
Note: This lesson may benefit from being broken up into two or more parts.

Lesson 2) MICROBES – GOD HAS MADE SOME LIVING THINGS SO SMALL THAT WE CANNOT SEE THEM.
Objective 1: To show that there are living things that we cannot see.
We cannot see microbes without a microscope but they are real and alive. Some are harmful; others are necessary for life. They are found all over. An example of a microbe is yeast, which is used to make air spaces in bread. Yeast produces carbon dioxide, a gas.
(The teacher should put yeast into warm water. After a while there will be bubbles. We can see that yeast makes a gas and that it is alive.)

Objective 2: To recognize the term, microbe.

Lesson 3) AMMONIA IS CHANGED BY MICROBES
Objective 1: To show that microbes change ammonia into less harmful material.
Ammonia is toxic, but God has a plan. Microbes that God has put into the soil change much of the ammonia into nitrites and nitrates. Nitrites and nitrates are compounds of nitrogen that can be used by plants. Nitrites and nitrates are less toxic than ammonia. A plant can use some of the ammonia but too much would be toxic.
(Activity- We can test the water in the fish tank and the plant container for ammonia and nitrates.)

Lesson 4) PLANTS CAN USE THE NITRATES and NITRITES
Objective 1: To show that plants can use the nitrates and nitrites and will grow well
Most of the air contains nitrogen (79%) but plants cannot use it unless it is fixed into a chemical compound such as nitrites and nitrates. Plants use the nitrates and nitrites to make their own proteins. They cannot make proteins without nitrogen. Plants grow fast and better when they can get nitrates and nitrites.
An interesting side note: Lightning makes nitrates and nitrites from the nitrogen in the air.
(Activity - We can measure the plant growth and record it, showing that the nitrates and nitrites benefit the plants.)

Lesson 5) COMPLETING THE CYCLE AND WATCHING FOR PROBLEMS
Objective 1: To get students to think about how the aquaponics system can become out of balance.

In nature, fish can eat the plants and complete the cycle. The system can become out of balance. In our aquaponics system, if the fish are fed more than they can eat, the food will add ammonia to the system. If a fish dies, it can add more ammonia to the system. If there are not enough plants the ammonia, nitrates and nitrites will increase to toxic levels. The nitrogen cycle is part of God's order in Creation, but we have to keep it in balance.

Thinking about balance and problems in the system -
Questions for the students

1. What will happen if there are too many fish in the system or if they grow too large? What should we do?
2. What if there are not enough fish?
3. What happens to a fish that dies? How can that cause a problem?
4. What if fish food is not eaten?
5. What if there are not enough plants?
6. What if there are too many plants?

Lesson 6 Review: EXPLAINING HOW THE SYSTEM WORKS - EVERYTHING GOES SOMEPLACE
Objective 1: Review – Students should be able to explain how the system works when questioned by the teacher.

When encouraged with questions the student might say that the fish produce waste with nitrogen in it, which is toxic. The microbes change it into less harmful material. The plants can use this to grow. When we feed the fish, we are feeding them plants, so the cycle is complete.
What comes out of the fish? (ammonia)
What if there is too much ammonia? (toxic to living things)
What changes the ammonia into nitrites and nitrates? (microbes that we cannot see)
What can use the nitrites, nitrates and some of the ammonia? (plants)
What do the plants do with nitrites, nitrates and some of the ammonia? (make proteins)
How do we get proteins? (eat plants and fish)
What do we need protein for? (muscles, skin and other things)
Does ammonia come out of us when our proteins wear out? (yes)

Objective 2: Assessment – Summative

Appendix B: Surveys

Teacher Survey

1) Rate your interest as a student of science when you were in elementary school. (Circle one)

Low		Medium		High
1	2	3	4	5

2) Rate your interest in teaching science to students in your classes. (Circle one)

Low		Medium		High
1	2	3	4	5

3) Rate the interest level of your students to learn science. (Circle one)

Low		Medium		High
1	2	3	4	5

4) What do you like about teaching science?

5) What do you consider to be challenges to teaching science?

6) Rate your confidence level in properly integrating Scripture into the teaching of science? (Circle one)

Low		Medium		High
1	2	3	4	5

7) What do you understand STEM education to mean?

Student Survey

1) Rate your interest to learn science. (Color one)

Low Medium High

2) Rate how important you feel the learning of science is to your life. (Color one)

Low Medium High

3) What do you like about learning science?

4) What do you consider to be challenges to learning science?

5) What do you understand STEM education to mean?

Appendix C: Formative Assessments

- Observation checklist

Student Name/ Grade	Attendance (per lesson)							Participation – asking questions, sharing ideas and answers						
	#1	#2	#3	#4	#5	#6	#7	#1	#2	#3	#4	#5	#6	#7
Student #1														
Student #2														

Meaningful interactions per lesson: 5 or more **(+)**, 3 or 4 (+), 2 or fewer (-)

- STEM education worksheets and activities – anatomy of fish, aquaponics cycle, math measurements, and writing activities with pictures.
- Reflection – Children were asked to reflect on their learning listing new things they learned and what other questions they might have or what more they would like to learn related to aquaponics and nutrition. Children were also asked to reflect on what this learning means for them as Christians. Responses were gathered orally as a group. The teachers led the discussions and recorded answers on the white board.

Appendix D: Summative Assessment Rubric

Summative Assessment Rubric - End of the unit rubric

OUTCOME	*TASK*	**Highly Competent (3)**	**Competent (2)**	**Developing (1)**	**Not Yet Evident (0)**
Student will be able to explain the nitrogen cycle in an aquaponics system	*Through a drawing, student will explain how an aquaponics system works*	Student was independently able to explain the nitrogen cycle (100%)	Student was mostly able to explain the nitrogen cycle (75%)	Student was able, with prompting, to explain the nitrogen cycle (50%)	Student was unable to explain the nitrogen cycle (25% or less)
Student will be able to explain the possible health benefits from aquaponics	*Student will describe to the teacher the possible health benefits*	Student could explain 3 or more health benefits	Student could explain 2 health benefits	Student could explain 1 health benefit	Student was unable to explain health benefits

Comments:

Appendix E: Attendance and Participation Checklist

Table 3

Attendance and Participation Checklist

Student Grade & ID	Attendance per lesson √ = Attended; X = Absent							Participation – meaningful interactions (-) = 2 or less; (+) = 3 or 4; (*) = 5 or more						
	L1	L2	L3	L4	L5	L6	L7	L1	L2	L3	L4	L5	L6	L6
3 a-m	√	√	√	√	√	√	√	-	+	+	*	*	*	*
3 b-f	√	√	√	√	√	√	√	*	*	-	+	*	+	*
3 c-m	√	X	√	√	√	√	√	*	X	*	*	*	*	*
3 d-m	√	√	√	√	√	√	√	+	+	*	*	+	*	*
3 e-f	√	√	√	√	√	X	√	-	*	+	+	*	X	*
3 f-f	√	√	√	√	√	√	√	*	*	*	*	*	*	*
3 g-m	√	√	√	√	√	√	√	+	-	+	*	*	+	*
3 h-m	√	√	√	√	√	√	√	+	+	+	+	*	*	*
3 i-m	√	√	√	√	√	√	√	+	*	*	*	+	*	*
3 j-f	√	√	√	√	√	√	√	*	*	*	*	*	*	*
3 k-m	√	√	√	√	√	√	√	-	-	+	+	*	+	*
3 l-f	√	√	√	√	√	√	√	*	*	*	*	+	*	*
3 m-m	√	√	√	√	√	√	√	+	*	*	*	*	*	*
3 n-m	√	√	√	√	√	√	√	+	-	+	*	*	*	*
3 o-f	√	√	√	√	√	√	√	*	*	*	*	*	*	*
3 p-m	√	√	√	√	√	√	√	-	+	*	+	*	*	*
3 q-m	√	√	√	√	√	√	√	*	*	*	*	*	*	*
4 A-F	√	√	√	√	√	√	√	+	+	*	*	*	*	*
4 B-M	√	√	√	√	√	√	√	-	+	+	*	+	*	*
4 C-F	√	√	√	√	√	√	√	*	*	*	*	*	*	*
4 D-F	√	√	X	√	√	√	√	+	+	X	-	+	*	*
4 E-M	√	√	√	√	√	√	√	*	*	*	*	*	*	*
4 F-M	√	√	√	√	√	√	√	+	-	*	*	*	*	*
4G-F	√	√	√	√	√	√	√	*	+	*	+	*	*	*
4H-M	√	√	√	√	√	√	√	-	-	+	+	+	+	*
4 I-F	√	√	√	√	√	√	√	*	*	*	*	*	*	*
4 J-M	√	√	√	√	√	√	√	+	*	+	*	*	*	*
4 K-M	√	√	√	√	√	√	√	-	+	-	+	+	*	*
4 L-M	√	√	√	√	√	√	√	*	*	*	*	+	*	*
4 M-M	√	√	√	√	√	√	√	*	*	*	*	*	*	*
4 N-F	√	√	√	√	√	√	√	*	*	*	*	*	*	*

Appendix F: Formative Assessment Results

Table 4

Formative Assessment Results

	Formative Assessment Results √ = Completed; X = Incompleted					
Student Grade & ID	Attendance and Participation	Anatomy of a Fish	Aquaponics Cycle	Math Measurement Activities	Writing Activity	Reflection
3 a-m	√	√	√	√	√	√
3 b-f	√	√	√	√	√	√
3 c-m	√	√	√	√	√	X
3 d-m	√	√	√	√	√	√
3 e-f	√	√	√	√	√	√
3 f-f	√	√	√	√	√	√
3 g-m	√	√	√	√	√	√
3 h-m	√	√	√	√	√	X
3 i-m	√	√	√	√	√	√
3 j-f	√	√	√	√	√	√
3 k-m	√	√	√	√	√	X
3 l-f	√	√	√	√	√	X
3 m-m	√	√	√	√	√	√
3 n-m	√	√	√	√	√	√
3 o-f	√	√	√	√	√	√
3 p-m	√	√	√	√	√	√
3 q-m	√	√	√	√	√	X
4 A-F	√	√	√	√	√	√
4 B-M	√	√	√	√	√	X
4 C-F	√	√	√	√	√	X
4 D-F	√	√	√	√	√	√
4 E-M	√	√	√	√	√	√
4 F-M	√	√	√	√	√	√
4G-F	√	√	√	√	√	√
4H-M	√	√	√	√	√	X
4 I-F	√	√	√	√	√	√
4 J-M	√	√	√	√	√	√
4 K-M	√	√	√	√	√	√
4 L-M	√	√	√	√	√	X
4 M-M	√	√	√	√	√	√
4 N-F	√	√	√	√	√	√

Appendix G: Summative Assessment Results

Table 5

Summative Assessment Results

Student Grade & ID	Summative Assessment Results HC = Highly Competent (3); C = Competent (2); D = Developing (1); NYE = Not Yet Evident (0) Task 1 Through a drawing, student will explain how an aquaponics system works	Task 2 Student will describe to the teacher the possible health benefits
3 a-m	C	C
3 b-f	C	C
3 c-m	D	C
3 d-m	C	HC
3 e-f	C	C
3 f-f	C	C
3 g-m	C	HC
3 h-m	D	D
3 i-m	C	C
3 j-f	C	C
3 k-m	D	C
3 l-f	C	C
3 m-m	C	HC
3 n-m	D	C
3 o-f	C	HC
3 p-m	C	C
3 q-m	HC	HC
4 A-F	C	HC
4 B-M	C	C
4 C-F	C	D
4 D-F	C	C
4 E-M	HC	C
4 F-M	C	C
4G-F	C	C
4H-M	D	C
4 I-F	C	C
4 J-M	C	HC
4 K-M	D	C
4 L-M	C	C
4 M-M	C	HC
4 N-F	HC	HC