Low Cost Group WASH Facilities: A scalable Solution for Hygiene Promotion in Primary Schools?

FUNCTIONALITY ASSESSMENT OF A NEW DESIGN APPROACH

Master Thesis

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Abstract

Diseases related to a lack of hygiene, such as diarrhea and respiratory infections, are still a leading cause of death for children living around the globe. Since the simple activity of hand washing with soap has a great impact on health and wellbeing, several international development programs support these hygiene activities in schools of developing countries. GIZ's Regional *Fit for School Program* concentrates on simple and scalable activities in a daily school routine, to create long lasting hygiene habits and to promote a life with dignity. Health status and school performance are closely related: Students without infections or diarrhea can visit the schools more often, are more able to concentrate and have an overall better academic performance (UNICEF, 2012, p. 6).

The program aims to prevent infections with three supervised interventions in the school: Hand washing (1), tooth brushing with fluoride toothpaste (2) and bi-annual deworming (3). The hand washing and tooth brushing are organized in daily activities during the school day, supervised by the teacher. To perform these group activities, a group washing facility is needed, where several students can perform the hygiene interventions at the same moment. This saves time and is also more motivating for students and teachers. Several low cost group washing facilities are constructed by layman and workers in the Philippines, but many of them show challenges in durability and usability.

GIZ Regional Fit for School Program designed a new kind of group washing facility to face these challenges. It is called 'Core Module'. The design is low in cost, uses a minimum amount of water and also makes a scale up to other areas possible, since it can be prefabricated in a workshop and be delivered to the point of use without a lot of effort.

This study assesses the functionality of the Core Module, to clarify chances and weaknesses of the design in preparation for a scale up to other countries, in two ways. First, the microbiological effect of the Core Module will be tested. Secondly, the technical performance of 100 Core Modules in 50 schools in the Philippines will be assessed. The findings of both parts will lead to an improved design.

Acknowledgments

I would like to express my gratitude to Prof. Busse and to my supervisor Dr. Wilm Quentin, both from the Department of Health Care Management of the Technical University of Berlin, for their useful comments, remarks and engagement through the learning process of this master thesis.

Furthermore, I would like to thank the GIZ Fit for School Team in the Philippines and Cambodia for the support on the way, namely: Dr. Bella Monse, Nicole Siegmund, Anna Goelnitz, Melf Kuehl and Nina Adrion and Juergen Guschelbauer.

Also, I would like to thank the Lucio Larano from the Appropriate Technology Center of the University of Iloilo for his great help in producing the Facilities and conducting the assessment. In addition a 'Salamat Po' to the participants of my survey, who have willingly shared their thoughts and time with me.

Without the existence of Viva con Agua de Sankt Pauli e.V. I would never have experienced the exiting work in the WASH sector. I want to thank Benjamin Adrion, Hauke and Malte Schremmer, the supporters in Germany, Switzerland and Austria and Mirko Seifert.

I would like to thank my loved ones, who have supported me throughout the entire process, by paying the registration fee from time to time and reminding me of exams (Walter, Alex, Annika, Dominique and Benny), by keeping me harmonious and happy (Peter, Kim, Gina, Alex and Faser) and by helping me to follow my dreams and ideas (My brother and his wife, Mom and Dad).

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List of Abbreviations

ATC …………….	Appropriate Technology Center of the Central University of Iloilo
CM……………...	Core Module
DALY…………...	Disability-adjusted life year
Dep Ed.…………	Department of Education in the Philippines
EHCP…………..	Essential Health Care Program. Nationwide program under the mandate of the Department of Education, based on the Fit for School Approach
ER.………………	Enhancement Ratio. Number of enhanced Core Modules compared to total number of installed Core Modules at a school
GIZ……………...	Gesellschaft für international Zusammenarbeit GmbH
iHWWS…………	Individual hand washing with soap
STH….………….	Soil transmitted helminthes
UNICEF………..	United Nations Children Fund
VRGB…………...	Violet Red Bile Glucose (Agar Plate)
WASH…………..	Water, Sanitation and Hygiene
WHO……………	World Health Organization
WinS…………….	WASH in School

Background

Diseases related to lack of hygiene, such as diarrhea and respiratory infections, are still a leading cause of death for people in developing countries. A simple intervention to lower the risk of these infections is to wash the hands with soap. The medical purpose of hand washing with soap is to reduce the number of pathogens on hands, which can cause diarrheal diseases and pneumonia, which together are responsible for the majority of child death worldwide. More than 1.7 million children die per year under the age of five years because of poor hygiene (UNICEF & GIZ, 2013, pp. 5,20).

In order to give a background for related health issues and the importance in a global context, two agents will be described in more detail: Helminths and Bacterium. After that, the scientific evidence of hand hygiene interventions will be highlighted, followed by an introduction of hand washing programs in developing countries.

Infection Agents

Germ infections are caused by agents like bacteria, viruses, fungi and protozoa. In general, every infection can become a pathogen if present in a critical amount and at the wrong body site. Based on numbers by the World Health Organization (WHO) from 2014, *Soil Transmitted Helminthes* (STH) infections are the most common parasitic infections worldwide, with approximately 1.5 billion infected people worldwide, 24% of world's population. It is caused by worms like hookworms, ascaris and whipworms. It is especially prevalent in tropical and subtropical areas, where the infections are widely distributed. The infection is transmitted by eggs, which are present in human feces. These feces contaminate the soil in areas with poor sanitation where, for example, open field defecation is practiced. In the soil, eggs can get easily attached to vegetables. If they are not carefully cooked or washed before eating, the eggs can get into the human body. Eggs can also contaminate water sources. Children are especially at risk when they play in the dirt and put their hand in the mouth after. Morbidity is related to the amount of worms in the body and it depends on the kind of worm. The symptoms can range from intestinal manifestations like diarrhea, up to general weakness, impaired cognitive and physical development and anemia. Although safe and effective medicines are relatively inexpensive and widely available, the control of the infection is based on periodical deworming, improved sanitation to reduce soil contamination and health education in personal hygiene activities like hand washing with soap to prevent infections (WHO, 2014).

Examples of common types of pathogenic bacteria are salmonella and escherichia coli (E.coli), both are a part of the scientific family of Enterobacteriaceae, a large family of gram-negative bacteria, which 'is one of the most important groups of bacteria for man' (Baylis, et al., 2011, p. 4). The bacteria are widely present in the human intestinal system and in water and soil (a transmission route), but more than half of E.coli outbreaks are transmitted by non-food bourn routes (Bloomfeld, et al., 2007, p. 29). The presence of E.coli cultures are used in Europe as a standard test to evaluate the efficacy of hand hygiene agents (European Standard, 1997).

Figure 1 shows the 'F Diagram' by the World Bank, which explains the spread of pathogens through fluids, fingers, flies and fields. It also demonstrates where hand washing can break the chain.

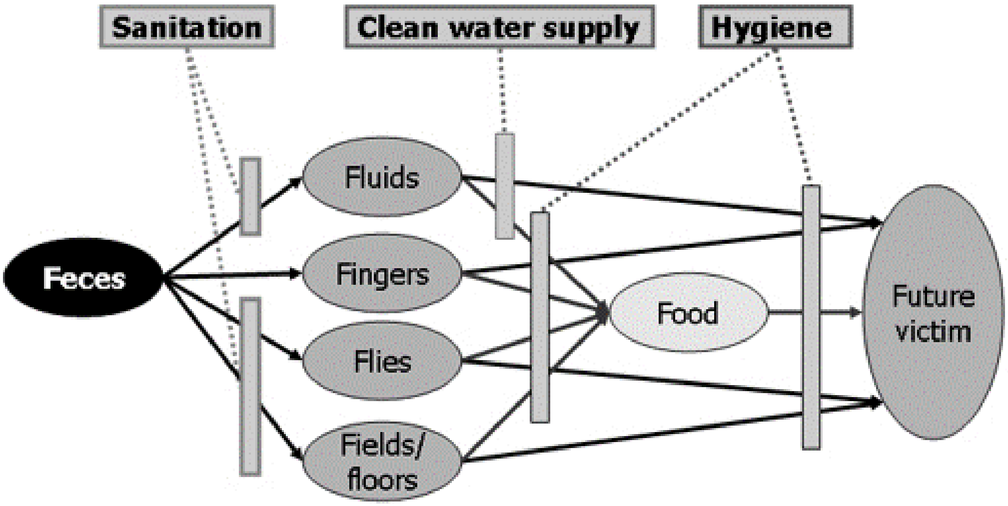


Figure 1: F Diagram (World Bank, 2014a)

The primary barrier is between the feces and the agents (fluids, fingers, flies, fields/floors). Important steps are the protection of the water source and the separation of feces from the environment. Hand washing is the important activity at the secondary barrier, before preparing or eating food. Another aspect is the hygienic preparation of the food. The combination of water, sanitation and hygiene issues is called WASH.

The scientific evidence of hand washing and current issues of discussion

The first evidence of a link between hand hygiene and the spread of infection was brought by Ignaz Semmelweis. In 1846 he observed different mortality rates of new born babies in two clinics in Vienna. He traced the differences back to *'cadaverous particles*' transmitted by the hands of the physicians, who had previously touched corpses in autopsies. After he convinced students and physicians to wash their hands with a chlorine solution after and before patient contact, the mortality rate dropped dramatically (Stone, 2001, p. 279).

Since Semmelweis, numerous other studies have proven the causal link between hand hygiene activities and the reduction of infections. For example, Sally et al. (2007, p. 53) point out that 'probably the single most important route for the spread of infections are the hands' and a risk reduction of 50-60% was observed when hygiene activities were implemented. In addition, Strunz et al. came in their Meta-Analysis to the conclusion that access to water and hygiene also appear to significantly reduce the odds of STH infection (Strunz, et al., 2014, p. 1).

Since it is proven that hand hygiene activities are an effective way to reduce the odds of infection (Strunz, et al., 2014; Stone, 2001, p. 279; Bloomfeld, et al., 2007), the discussion has turned to the efficiency of the different interventions. Various aspects are considered as important parameters in research studies. Oughton et al. (2009) looked deeper in the importance of the water temperature, Bloomfield clarifies the time issues in the meta-analysis (2007, p.45). Fuls et al. did the same in 2008 with the additional aspect of how much volume of soap is used - see also Larson et al. (1987). Boulder checked in 2008 the difference of hand floras from female and male participants, and Cogan concentrated his work on different hand washing techniques.

However most of the studies concentrate on the medical output and do not consider socio-economic aspects like behavior or the availability of water or cleaning agents. Even though a lot of studies were conducted, it is not yet determined what amount of water is actually needed for *'effective hand washing under most circumstances*' as a minimum standard (Shordt, 2006, p. 6). In studies, the quantity of water used is mostly not observed or controlled.

In times of increasing challenges related to water scarcity, the amount of water needed for hand washing becomes more and more important. Especially in places where STH infections are widely spread, water is a rare natural good or the availability is limited by infrastructural deficiencies or there is systematically limited access for poor people (United Nations Development Programme, 2006, p. 11).

The absence of the information about required water quantity is the motivation for the microbiological part of this study.

Hand washing in the development work context

This chapter gives a background of WASH interventions in developing countries, with a spotlight on the cost of hand hygiene activities and the place of intervention.

The inhabitants of less developed countries *'carry greater burden of morbidity and mortality'*, due to economic limitations to invest in hygiene and public health infrastructure (Aiello & Larson, 2002, p. 103).

In order to measure the burden of disease, the concept of disability-adjusted life years (DALYs) is used in scientific research and in political decision processes. DALYs express the burden of disease from a social perspective. It can be used to compare the effectiveness of interventions, by calculating information about years lived with disabilities and years of life lost. The concept uses the baseline of the highest national life experience (Busse, 2012).

Compared with other interventions in the WASH sector, HWWS is by far the solution with the highest cost-effectiveness ratio. Whereas the promotion of latrines would cost US$ 11 per DALY, household water connection more than US$ 200, but HWWS only costs US$ 3.35 (Cairncross & Valdmanis, 2008, p. 791). *WHO* declines that an intervention that averts one DALY for less than GDP per capita is considered to be highly cost-effective (WHO, 2015). The average per capita income in the Philippines is around US$ 2800 and in Cambodia US$ 1000 (World Bank, 2014d). So the intervention is highly cost-effective. The high cost-effectiveness ratio is one reason why plenty of development programs promote HWWS for an improved health situation.

Many programs identified school communities as a good environment to improve personal hygiene. If hand hygiene activities are promoted in schools, several studies have shown a benefit from the intervention for the whole community (Ejemot & al, 2008, p. 8).

The WASH in School (WinS) program by UNICEF names four principle reasons, why WinS is important (UNICEF, 2012, p. 6f):

1. Health: Schools with a functional WASH program can reduce the spread of diseases within a community.
2. Attendance: Diseases affect directly the participation and learning effects of students in school. With a functional WASH program, pathogens will be less. Through an increased attendance rate, also the performance will increase, which leads to economic growth of the society in the medium run.
3. Gender Equality: It is more common for girls to drop out of school when toilets or washing stands are not private or safe – or simply not available. With a functional WASH infrastructure, girls are more likely to stay in school and finish their school career.
4. Community Outreach: WASH in School enable children to become change agents for improved water and hygiene practices in their families.

There is a great health impact of hand washing and other WASH interventions in schools because school-aged children bear the greatest burden of morbidity due to soil-transmitted helminthes (UNICEF, 2011, p. 8) and infected children are physically, nutritionally and cognitively impaired (WHO, 2014). WinS has the chance to diminish absenteeism, a big global problem, especially for young girls. The WHO estimates 200 years of school days have been lost in the world due to absenteeism. In addition, the average IQ loss per worm infection is 3.75 points, equivalents 633 million virtual IQ points lost (WHO, 2005, p. 15). A study also proves that students with good hygiene behaviors were 20% less likely to be absent (Lopez-Quintero, et al., 2009, p. 98).

Onyango-Ouma et al (2005) figure out the potential of school children to be change agents within their community. Direct engagement with students along with interventions 'can lead to adoption of good WASH behavior' (Onyango-Ouma, et al., 2005). On the other hand, some studies also highlight the challenges of reaching parents (Freeman & Clasen, 2011; Rheingans & al., 2009).

Several projects of different national and supranational agencies, and non-government-organizations (NGOs) focus on the knowledge transfer. The priority is the education of hygienic behavior – for example, to wash hands after using the toilet and the technique of how to wash hands properly. Despite the existing knowledge that hand washing with soap is effective to prevent illnesses, the understanding is quite abstract and there is often no automatic behavior or habit in communities, schools or homes - often due to the fact that the infrastructure is not available or functional. To turn hand washing with soap into an integrated day-to-day habit is a great challenge for all programs. Neal highlights the importance to stimulate two brain systems through the intervention: the neocortex and the basal ganglia. Drivers for the neocortex are attitudes, social norms, rational benefits and emotions. Interventions often have a strong focus on these drivers. Habits and heuristics are drivers for the basal ganglia system. Neal defines nine principles to address this system, for example, a supporting environment and leverage context, to eliminate friction and intervention through doing. The combination of a habit strategy and the focus on the existing drivers lead to an augmented approach to create new habits (Neal, 2014). The supportive environment and the elimination of friction are two principles applied in the methods part to create an index, the Enhancement-ratio.

Fit for School Program

The aim of the GIZ *Fit for School* is to create and sustain this integrated daily habit. The Fit for School program is based on international health recommendations and promote a feasible, low-cost and realistic strategy, using the principles of health promotion outlined in the Ottawa Charter (Monse, et al., 2010). It started as a national NGO in the Philippines (*Fit for School Inc.*), later the GIZ adopted the approach and integrated it into a new regional program. GIZ school health program *Fit for School* provides technical assistance to the Department of Education (DepEd) in the Philippines. The program follows the principles *simple, scalable and sustainable*. The three core components of Fit for School approach are:

1) Supervised hand washing with soap in a daily group activity
2) Supervised tooth brushing with fluoride toothpaste in a daily group activity
3) Biannual deworming according to the guidelines of the World Health Organization (WHO) (Benzian & Wilson, 2012, p. 2).

The basic principle within the approach is the group activity of students. Students enjoy group activities more than individual tasks. Another important fact is the saved time during the school day – not more than 5 to 10 minutes are needed for the class to wash hands and brush teeth. (Monse, et al., 2011).

A longitudinal 4-year cohort outcome study in 2009 has demonstrated the positive effects of the interventions on health status, such as an increase of BMI, a lower prevalence of STH infections and a (non-significant) reduction of caries and dental infections (Monse, et al., 2013, p. 5f).

In 2012 the program was benefiting more than 2 million public elementary school children in 42 provinces of the Philippines. Following the demand from other Southeast Asian governments, the Fit for School approach was adapted to the specific national context in Cambodia, Indonesia and Laos PDR, where the program also works in close coordination with national partners. (Benzian & Wilson, 2012, p. 3).

In 2013, the core components of the Fit for School approach were adopted to the *Three Star Approach for WASH in Schools,* which is the base for UNICEF WinS programs worldwide to help ‘schools meet the essential criteria for a healthy and protective learning environment’ (UNICEF & GIZ, 2013, p. 2).

Group WASH Facilities

This part highlights the existing infrastructure for hand hygiene activities in schools and points out the challenges and findings from field observations in the four Fit for School Countries; Philippines, Cambodia, Laos and Indonesia

It is the universal right of children to have access to water and sanitation as part of a healthy learning environment, says the *Three Star Approach,* to underline the importance of WASH infrastructure at schools (UNICEF & GIZ, 2013, p. 3). Hygiene activities need an infrastructure where it can happen, and it is more likely to happen in schools where facilities are easy to use and accessible (Shantz, 2013, p. 4)

To make daily supervised hygiene activities in a group possible, facilities at the schools are needed where a number of students can perform hand washing or tooth brushing at the same time. In 2009, the Department of Education (DepEd) ordered the construction of washing facilities in all elementary schools (DepEd, 2009).

The GIZ Fit for School program encourages schools to build their own group wash facility, accordingly many different kind of facilities exist in schools. An assessment of these different facilities revealed challenges regarding the functionality and usability. Figure 2 on the next page shows sample pictures from the GIZ publication *Field Guide: Hardware for Group Handwashing Schools,* of common mistakes regarding the construction and usability of self-made facilities. The pictures reveal the challenges schools have, in order to build durable facilities with low-cost materials and limited resources. The main gap is often the sustainable funding for materials and spare parts, but, from time to time, there is also the lack of skilled labor. It can also be the case that the requirements for facility for groups are not given, and only one faucet is installed.

The Parent-Teacher-Association (PTA) is responsible within the school for several issues, to create a productive learning environment. For example, they purchase learning materials, help with maintenance activities or manufacture school uniforms. Often the PTA is also responsible for constructing a group washing facility. Participants contribute either time or money to construct a facility at the school area without any guidance or support. This can lead to problems. The decision making process within the PTA can be described with the *Garbage-Can-Model* by Micheal Cohen et al. Three points describe the process: problematic preferences, unclear technology and fluid participations. The participants often realize their preferences late in the process, the knowledge of available technology and structures are often insufficient, and the engagement of the participants depends on their time, or they drop out, since their children no longer attend the school. Following Cohen, decisions in these kind of organizations are not based on rational analysis, but occasional (Cohen, et al., 1972, p. 1).

Another factor is that schools are often unable to maintain the functionality of the facilities, since operational funds are insufficient and roles and responsibilities within the school community are often not clear (GIZ, 2013a, pp. 12, 29).

Often facilities are built with plastic materials, like PVC pipes are faucets, which are not hard-wearing enough to last for a long time in the schools, due to vandalism and normal abrasion. The lack of security at school compounds is often a reason why low price plastic materials are purchased instead of metal parts.

Overview common Mistakes			
Construction		Usability	
			
Unsupported Structure, flexible materials are more likely to break	Rotten wood structure, no sustainable materials were used	Narrow opening, refilling process complicated. Bucket too high to refill manually	Dimensions are not suitable, here the students can barely reach the faucet
			
To many holes, too big holes. High water consumption	Poor connection to water supply here to water bucket	Individual faucet is not suitable for group activities, long waiting time	Splashing of water over the bucket will wet the students.

Figure 2: Overview common mistakes (all pictures by (GIZ, 2013a))

More sophisticated WASH stands already exist. They were developed and installed by local NGO or companies. The picture on the right side shows a facility in a primary school in Phnom Penh Cambodia, serving 68 students. The water comes from the main system of the school. The basins are four meters long and can accommodate nine students at the same time per side. The material costs are 353 US$, so this is an investment of 5$ per student (GIZ, 2013b). Unfortunately the funding of schools are limited and not many schools can effort a facility like that, with a yearly budget for WASH investments (including soap) of around 60 $ (Shantz, 2013, p. 17). Another limiting factor for these kind of facilities are the materials, which might not be available in the rural areas. This type of washing facility is not suitable for mass production and it is simply too expensive for many school communities in South-East Asia. A scale up in a large quantity of schools is not possible with this kind of technology.

Figure 3: Facility in Cambodia

Another important topic is the water consumption of washing facilities. A bottleneck analysis by UNICEF shows that only 62% of schools in the Philippines have access to improved water (UNICEF, 2011, p. 40), in Cambodia 42% of schools do not have access to improved water (UNICEF, 2014). WASH stands cannot be simply attached to a main water system like in the picture, if there is no pipe system. Further, experiences have shown that schools have problems with paying water bills (GIZ, 2013a, p. 12), due to a higher amount of water needed for hygiene and sanitation infrastructure. In a report from 2012, the Commission on Audit (COA) in the Philippines detected that hand washing facilities built by the Department of Education, '*were mostly not functiona*l', due to lack of water (COA, 2014, p. 6).

GIZ's review of community-built facilities (see figure 2: overview common mistakes) across South-East Asia shows that communities are good and very creative in constructing different solutions, but school communities across the region face challenges to produce fully-functional, water-efficient and durable solutions. In addition, many school heads (83%) are not satisfied with the hand washing facilities in the schools (Shantz, 2013, p. 15)

Based on this analysis and the rising demand for durable and scalable infrastructure solutions for personal hygiene in primary schools, the idea emerged to design a group washing facility which is durable, low in costs and scalable. The facility should be pre-fabricated, to ensure quality and efficiency, in a central place of the region. In addition, a pre-fabricated facility helps schools to prevent a 're-inventing of the wheel', a reason why many resources are often lost (Cantwell, 2014, p. 4). Since this design is an essential part of hygiene activities in schools – but not the final setup – it is called "*Core Module*".

Core Module: Engineering Design Process

In the beginning was the identification that school communities would need more help and guidance to set up sustainable and affordable hand washing infrastructure. As in every development process, the product is never 'final' or 'perfect'. It needs to be assessed and checked frequently to improve it step by step. The development process of the *Core Module* is strongly inspired by the Engineering Design Process (EDP). The EDP is a series of steps to meet desired conditions of a system, process or product. It includes research, prototyping and assessment (ABET, 2014). The figure on the right shows the

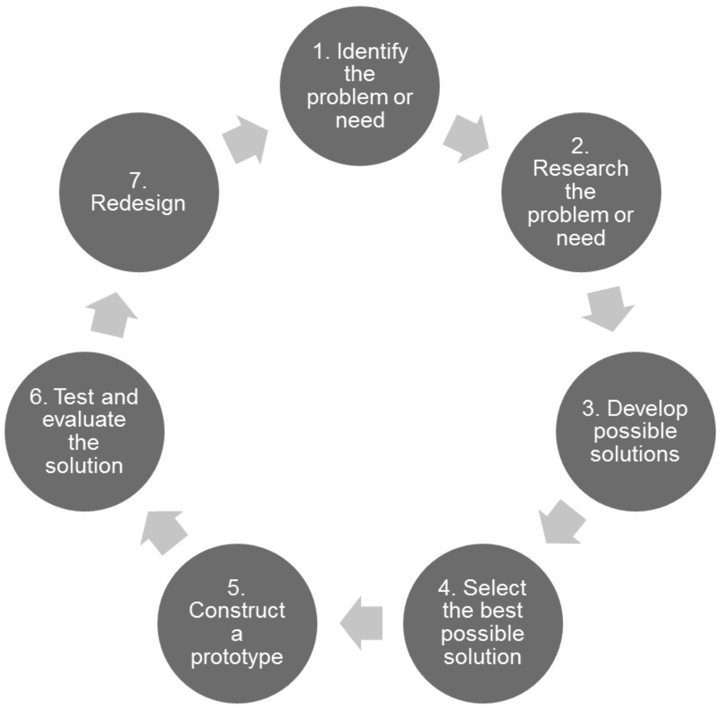


Figure 4: Engineering Design Process

steps of the systematic approach.

The following pages describe the evolution of the Core Module from the first prototype in Germany to the first field tests and assessments in the Philippines. It is demonstrated how the design - which will be checked in this study - was developed to strengthen the understanding of important technical and user issues.

First Design

As mentioned, the new facility has been developed by GIZ primarily to ensure functionality and durability. GIZ mandated, in summer 2013, a product designer in Germany to create a design for washing facilities or different options depending on the availability and cost of local materials. (GIZ, 2013c) Out of several ideas, GIZ decided to develop a design which is defined by a GI (galvanized iron) pipe system. The first design is shown in the picture on the right. The facility contains a six meter (20 feet) long GI pipe, two union connections, two tee connections, one ball valve, one plug and two double nipples. All materials are galvanized. The galvanization adds a protective zinc coat to the iron, which makes it corrosion-resistant. The length of 6 meters is an industrial standard dimension for the GI pipes. The total pipe is cut in one 3m long section and two 1.5m long parts for the posts. The posts and the 3 meter long pipe are connected to the posts with a union connection, a double nipple and a tee connection, as the figure number six shows. The union connection consists of two female ends and a nut, and allows fast a connection of two parts without a relative rotation to each other. A rubber plate within the union

Figure 5: First Design Study

Figure 6: Close up water supply

connection prevents water running in the posts, which may influence the water quality and stability of the system. The water pressure is managed by a manually elevated bucket, but also the connection to a water system would be possible (see picture 6). At the water bucket (white bucket at picture 5) a faucet opens the water run. A flexible garden hose connects the water bucket to the pipe system. The garden hose was selected to allow several possibilities for the elevation of the bucket for the user. Water runs through the ¾ inch pipe and drops out at ten bore holes, each with a diameter of 1mm. The small diameter was used to keep the water consumption as low as possible (how much it really is will be tested in the microbiological test).

With the ten bore holes, the facility can accommodate 20 students at the same time, two students per bore hole, one from each side. After the first bore hole a ball valve is placed, to make it also possible to use the Core Module for individual hand washing.

This design was the starting point for field testing in the GIZ Fit for School Program countries. The Philippines is the pioneer country for the *Fit for School* approach, this is why most of the testing takes place there.

Philippines Prototype and Field Testing

More than 100 million people live in the Philippines, which makes it the 12th biggest country in the world. The nominal GDP is 2.943 US$ per capita (estimated in 2014), which makes it a low middle income state, as defined by the World Bank (World Bank, 2014b). In 2013, more than 14.5 million students were enrolled in nearly 38.000 primary schools (an increase of 9.5%). Through school attendance is compulsory, in 2010 nearly 28% of elementary aged kids did not complete primary school (DepEd, 2010). The enrolment ratio is in the Philippines is nearly 15 percent points less than in the rest of the East Asian and Pacific (World Bank, 2014c). The national education budget in 2014 is around 284 US$ per child (7.07 billion US$ in total) (Official Gazette, 2014).

In the Philippines, the idea of the first design was picked up and a first improvement was created. For the German prototype it was necessary to open the water system at the elevated bucket to make hand washing possible, this could be a problem especially when small children want to wash their hands individually. In Cagayan de Oro, a prototype was designed with an additional tee connection and a plastic faucet, to allow individual hand washing. With a faucet, which can be open and closed by students, it is possible to have water pressure on the facility all the time – a faucet at the bucket to open the system is not required anymore.

Market observation in different regions of the country prove that in general the materials are available in the Philippines, but the connection of the garden hose to the facility and the water bucket are problematic. Sealing rings or bulkheads, for the connection at the bucket, are not widely available.

Figure 7: Core Module with faucet

In late October 2013, the first installations of Core Module prototype were done in San Isidro, in the north of Manila. The prototype was designed, as mentioned earlier, to be durable and functional. In addition, it leaves space for community engagement and enhancements.

Figure 8: Beautification activities in school

To raise ownership and to promote a careful treatment of the facility, it leaves space for the community for beautifications. In the picture, students paint the facility. These beautification activities strengthen the ownership of the facility by the community.

The installed prototype in San Isidro was the first Core Module which was installed at a school. Observation and feedback from students, teachers and plumbers, gave new input for the EDP to improve the Core Module. Table 1 gives a simplified overview of the EDP.

Core Module – Engineering Design Process	
Steps	**Examples**
Identify the problem	Group WASH Facilities are not functional, little water consumption is appropriate
Research the problem	Materials, Costs, Common Mistakes
Develop possible solutions	Different materials and set ups
Select the best Solution	GI Pipe System
Construct Prototype	Philippines Prototype
Test and evaluate prototype	San Isidro Test School, More Stability is needed
Redesign	Additional Post

Table 1: Core Module - Engineering Design Process

The feedback of students and teachers was used to create a new improved facility: An additional post in the middle of the facility increases the stability of the module. Following the results of the EDP loop, the new design looks like this:

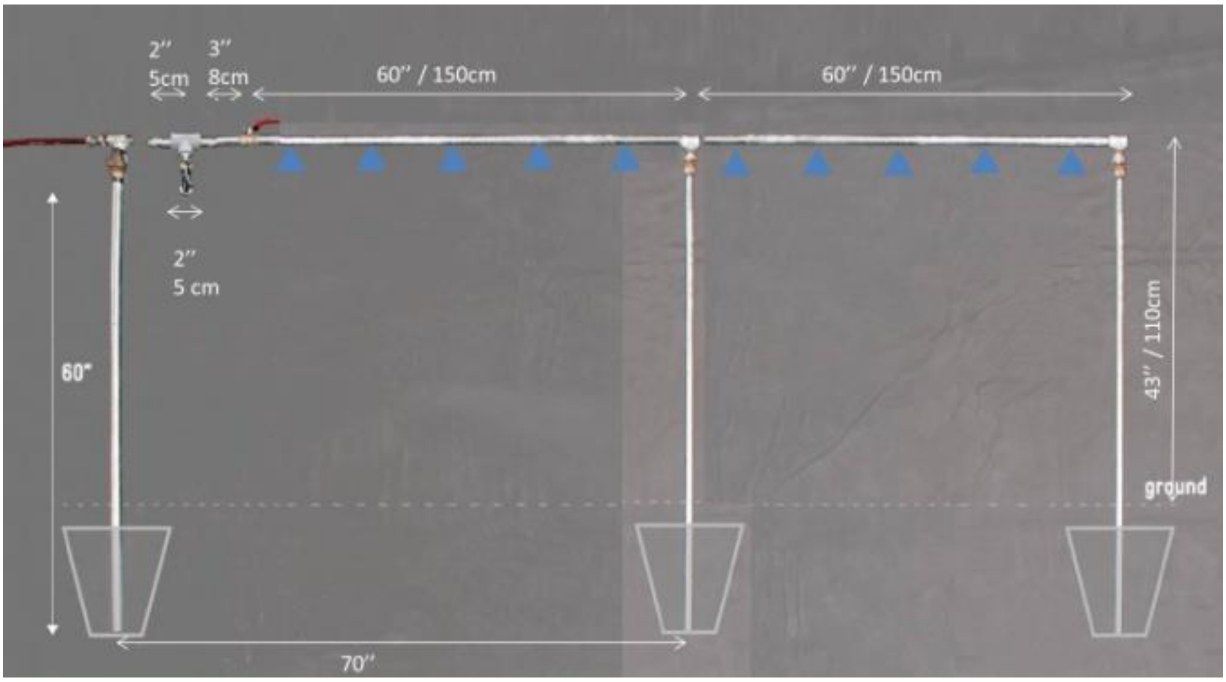


Figure 9: New Design of the Core Module after first EDP Loop

The following table shows the bill of quantities for the required materials to produce one Core Module, as well as costs.

#	Item	Unit	Quantity	Price	Costs in PHP
1	Galvanized Pipe ¾ , Sch. 40	feet	25.00	19.10	477.50
2	Double nipple ¾ x 2 inch	pcs	3.00	16.00	48.00
3	Double nipple ¾ x 5 inch	pcs	2.00	20.00	40.00
4	Tee (¾ female)	pcs	4.00	40.00	160.00
5	Ball valve (¾female)	pcs	1.00	210.00	210.00
6	Faucet	pcs	1.00	70.00	70.00
7	Reducer ¾ to ½	pcs	2.00	15.00	30.00
8	Union Connection (female thread)	pcs	3.00	110.00	330.00
9	Plug (¾ male)	pcs	1.00	9.00	9.00
10	Teflon Tape	roll	3.00	15.00	45.00
11	Rubber Sheet	pcs	1.00	13.00	13.00
12	Bucket (6l Water, for foundation)	pcs	3.00	47.75	143.25
13	Cement	45 kg sack	0.13	220.00	28.60
14	Sand	m³	0.06	550.00	33.00
15	Water Bucket (5 gallons)	pcs	1.00	134.00	134.00
16	Double Nipple ½ x 2''	pcs	1.00	13.00	13.00
17	Garden Hose ¾	meter	3.00	35.00	105.00
18	Connection to Garden Hose ¾	pcs	1.00	70.00	70.00
19	Hose Clips ¾	pcs	2.00	9.00	18.00
20	Plastic faucet for the bucket	pcs	1.00	60.00	60.00

Table 2: Bill of Quantities

All materials are widely available, also in rural areas. Local plumbers were able to produce the Core Module without a lot of guidance or help.

As mentioned earlier, the financial situation of the school communities is tense, so a high price would stand against a mass fabrication. Since costs for materials are less than 46 US$, a scale up seems to be economically affordable.

Typhoon Haiyan (Yolanda)

On November 6th, 2013 the tropical cyclone Haiyan (locally known as Yolanda) hit a wide spread area of the Philippines, including Conception, Iloilo. At least 6300 people died, making it the deadliest storm in the Philippines history, and nearly 16 million citizens were affected. The total damages are worth nearly 2 billion US Dollars (NDRRMC, 2014).

Figure number 10 gives an overview of the path of the storm over the Philippines.

In the affected areas, more than 3,200 school buildings (about 90%) were damaged, where normally 1 million students learn and more than 34,000 teachers work

(Valcarcel, 2013). As a part of the humanitarian aid to assist schools in affected areas, DepEd requested assistance by GIZ.

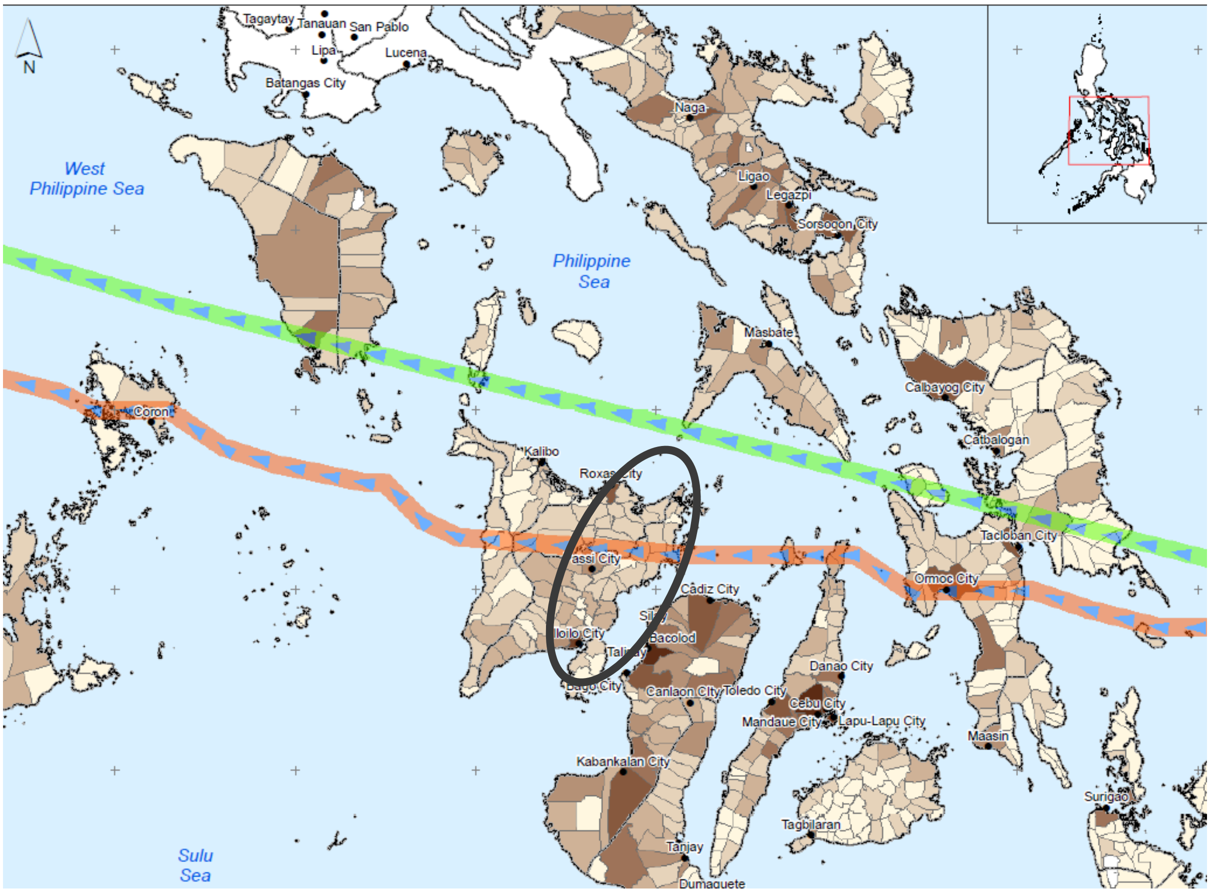


Figure 10: Path of Haiyan (in red actual storm path, green predicted storm path (MapAction & OCHA, 2013))

The Fit for School program assists with production and installation of 100 Core Modules to support 50 schools in the province of Iloilo, at the east coast of the island of Panay (encircled on the map). The Core Module helps the school community to improve their hygiene situation, also in situation with unstable or broken water supply. In addition, Fit for School provided hygiene kits - including soap, toothpaste and toothbrush and sanitary napkins - for nearly 20,000 students.

The 100 installed Core Modules are the data base of the technical assessment of this study.

Production Process

The production site for 100 Core Modules was in Iloilo City, the capital city of the province Iloilo in the south of the Island Panay. The town was not affected by the typhoon, so the infrastructure and materials supply was in order.

The production partner at the Central Philippine University (CPU) was the Appropriate Technology Centre (ATC). The Centre was equipped with all necessary tools and had group of skilled workers, who were able to produce the facilities. The objective was to prefabricate the facilities in the workshop, to facilitate a fast and efficient installation at the school ground later.

ATC contracted four students, who had already experienced working with the needed tools and GI parts, but were not trained plumbers or engineers. GIZ conducted in November 2013 a one day orientation workshop, to learn how the facility is produced and what issues are important. Once the workshop was equipped, all process steps were clear and all tasks were distributed, ATC could fabricate eight to ten facilities a day.

To fabricate the Core Module, only a few tools are needed: A pipe die to cut the thread into the pipe; a cut off saw; pipe wrenches for the preassembling and a vertical drill.

Figure 11: Production Process at ATC. Cutting threads with die and drilling bore holes

All of the non-power tools were available at the workshop. The vertical drill requires power, and was not available.

The following part explains the prefabrication process of a Core Module at ATC.

First, the GI pipe is cut into the required lengths: two times 150cm for the water pipe system and 3 times 150cm for the posts. For a mass production, the chosen dimensions leave no leftovers of pipes. One end of the post pipes needs to be threaded with a die, to make an attachment to the union connection possible. At the water pipe, both sides need to be threaded. The feet of the posts were fixed in cement as the foundation. This was part of the prefabrication, to accelerate the installation in at the school compound. The water pipe was drilled with a 1.5mm drill bit. All threads were covered with Teflon tape, to prevent leaking.

At the end, a prefabricated Core Module consists of 4 items:

1. One 3 meter long Water-Pipe-System, including faucet for individual hand washing and ball valve for group activities
2. Three posts with a concrete foundation
3. A five gallon slim blue bucket with a tailor made solution with a faucet to attach the two 2.5 gallon slim blue buckets for refilling
4. Garden hose to connect the gallon with the Core Module

Installation

Also in the responsibility of ATC was the delivery and installation to the schools. The target schools were chosen by the DepEd. The population and location of the schools are shown in the methodology chapter. ATC delivered the facilities with a pickup truck starting in the south, going north. Depending on the location of the school, the accessibility (due to road conditions) and the number of facilities for the school, ATC installed four up to twelve facilities a day with four up to six workers.

For the final installation the worker need a shovel, two pipe wrenches, a meter and a water level. The assistance by the school community members for the installation was set to a minimum, keeping the disruption at the school ground and in private homes in mind. In some schools, PTA-Members assist. In all schools, the principal or a teacher in charge decided at what location the Core Module should be installed. ATC installation team and GIZ gave assistance in choosing the right place. For example, it was recommended to find a spot where students can access the facility from both sides and, if possible, also a roofed or fenced area to protect the facility from thefts and the students from sun and rain. Also, a possibility to elevate the water bucket nearby was considered. In the end, the decision where to install the facility is within the responsibilities of the school authorities.


Figure 12: Installation Team with full Core Module package

The installation of the Core Module is finished in around 30 minutes – depending on the nature of the soil. First the three posts are connected with the union connection to the water pipe system. The sealing plate was placed in the union connection, to avoid standing water in the posts. Then three holes were dug, where the concrete foundations of the posts are placed. Since the pipe system needs no slope, the water pipe was leveled with a water level. After closing the holes again with soil, the facility was checked for leaks one last time. Finally, it was demonstrated to teachers and students how the Core Module works.

The principal received an introduction to cleaning and maintenance activities and tips on how the bucket can be elevated or what kind of basin they can easily build, out of their school resources.

Objective of the study

This chapter clarifies the objective of the study and gives an overview of the structure of how the main questions will be answered.

After prefabrication and installation, it needs to be assessed how the facility works within the school community day by day. To start a new loop in the EDP for further improvement, information from the users in the field are needed to clarify problems and challenges. The main question of this study reads as follows:

Is the 'Core Module' functional for the use primary schools?

To answer this main question, '*Functionality'* will be assessed in two sectors: microbiological and technical.

Due to the fact that the core module was designed to use only a little amount of water for washing activities, the question emerged whether this little amount of water is enough to wash hands, with the same germ reducing effect like with a regular system for individual hand cleansing. This question must be answered to clarify if the core module is also functional in a microbiological sense, to promote health and reduce the risk of bacterial infections through hands.

The technical sector is defined by the two aspects *Construction* and *Usability*. Construction covers aspects like the process quality and the durability of used materials used, as well as the water management. *Usability* is focused on the accessibility and contentment of the users with the Core Module at the school.

The results of the study will provide a detailed answer to the question as to whether the core module is functional in both sectors: technical and medical. The findings of this study will address the chances and limitations of the Core Module in a real-life setting and clarify if it is useful as a scalable solution to face the challenges of poor hygiene in school communities. The gathered information from both sectors will be utilized as the base for a redesign, based on the EDP-Circle (see Figure 4), so the answer to the main question (*is the Core Module functional for the use in schools?)* will decide a new design of the facility.

The table below gives an overview of the Study Structure. The main question is separated – as mentioned – to two sectors. Each sector is defined by aspects (hand hygiene, construction and usability). Several indicators are created to assess the aspects. Methods, which will be described in detail later, were chosen to give quantitative and qualitative data for the indicators.

Study Structure			
Main Question	Is the Core Module functional?		
Sectors	**Microbiological**	**Technical**	
Aspects	Hand hygiene	Construction	Usability
Indicators	• Germ reducing effect • Water consumption • Efficiency	• Durability of materials • Processing Quality • Water Management	• Satisfaction • Accessibility
Method	Microbiological Trial	Assessment Form	

Table 3: Study Structure

The first section of the study will focus on **microbiological functionality** of the Core Module. A hand washing trial was conducted to test the ability of the Core Module to be as effective in germ reducing as a normal faucet – while consuming less water.

An assessment of the 100 facilities in 50 schools in Iloilo was carried out to clarify the **technical functionality** of the Core Module after several months at a school.

Unfortunately, aspects like behavior change in personal hygiene or long term health impacts will not be considered in this study. Although tooth brushing is a core part of the *Fit for School* approach, the assessment of this activity will go beyond the scope of this study.

Methodology

The following chapter describes the methodologies used in each sector of the study. First, the methods for the microbiological trial will be explained, followed by the technical assessment. The results will be presented later separately, and the merge of both sectors leads to a redesign of the tested Core Module design, to make it more applicable for the usage in schools.

Microbiological Sector

Several studies have proven that ‘hygiene is paramount to resolve the problem’ of diarrheal diseases and at least 2 million deaths of children each year (Curtis & Caimross, 2003, p. 73). However, as mentioned earlier, the minimal amount of water needed to ensure effective hand washing is not yet clarified (Shordt, 2006, p. 6). Due to the design of the facility, the water runs through a punched pipe with tight bore holes of 1.5mm and the water consumption is very low.

This trial was conducted to clarify if the use of the Core Module does result in any difference of bacterial contamination on hands after hand washing, compared to an individual hand washing station with a normal faucet. In the same trial, it was measured how much water is used in each intervention.

Subjects

In the controlled study 18 subjects participated. All subjects, recruited from the GIZ Office in Manila, were at least 18 years old and the study demographics was mixed for age, sex and race. Dermatosis or other injuries to the skin that would have compromised the subject or the study, were exclusion criteria. All subjects volunteered to participate in the study and were aware of the trial design and the objective of the study.

Study design

A controlled study assessed bacterial hand contamination before and post-hand washing in two arms:

1) Individual hand washing at a standard faucet (iHWWS)
2) Hand washing in a group activity of 18 persons at the Core Module (CM)

Before and after hand washing, the dominant hands of the subjects were sampled for enterobacteriaceae, as described in detail below.

Each of the 18 subjects gives one sample of finger pads before and one sample after each intervention. Each volunteer performs one time at the individual hand washing station and once at the Core Module. Hence 72 direct contact tests (DCT) were collected in total (36 before hand washing, 36 after hand washing). The sample size of 18 is because of two reasons: First, the facility is designed to serve 22 users at 11 holes. For the trial, the amount of water used per bore hole was measured at the first and last hole, so only 9 holes for 18 people were available. The other reason is the recommendation in the European Standard EN 1500, which defines hand-rub test methods and requirements. This method requires 12-15 test volunteers (European Standard, 1997). To avoid learning effects, the group of 18 people were divided into two smaller groups of 9 volunteers. One group performed individual hand washing in the morning session and group activity at the Core Module in the afternoon session, the other group did it the other way around.

Hand washing procedure

All subjects received instructions by a medical doctor in hand washing technique to ensure proper skills. Nine steps were adopted from the Fit for School Manual for Teachers (Monse, et al., 2011, p. 12f), what is notable is that the subjects did not use a towel to dry hands. On both arms, subjects applied soap (Ivory original soap bar, 45g) on their hands and lathered for 20 seconds. The water temperature was maintained at 26°C ± 2°C.

Of course, the amount of water used in each intervention was not given, in order to have realistic findings about the water consumption. Also, the time spent wetting the hands and the time of rinsing was not predefined. At the individual hand washing stand, the subject decided on his/her own as to how much time they needed to wet and rinse their hands, and how much water was used was defined this way. Within the group activity, the investigator opened the water supply (with his non dominant hand) before wetting and rinsing. The volunteer raised her/his hands in the air, as soon as he decided that the wetting and rinsing process was sufficient. After all participants raised their hands, the investigator closed the water supply.

Water quantity per Intervention

To measure the amount of water consumed with the different interventions, the used water at the individual hand washing stand was collected with a bucket and measured after each procedure. So at the individual hand washing stand, the measurement is exactly per person.

At the Core Module the first and last (11th) bore hole was prepared with a bucket to collect the leaked water. The water consumption X per bore hole *j* was calculated with a linear function: (also see 'Experimental Setup')

$X_j(\beta, \gamma) = \beta + j \times \left(\frac{\gamma - \beta}{10}\right)$, with j = [1,…,9]; γ= liter in bucket 1; β= liter in bucket 2

The assumption is that both subjects using one bore hole from both sides, consume the same amount of water (Water consumption of subject i at bore hole j: $\frac{X_j}{2}$)

Bacterial recovery and enumeration:

Bacterial contamination of finger pads was assessed with a direct contact test (DCT) method on *Violet Red Bile Glucose Agar* (VRBG) plates (9cm diameter). This is an adoption of existing methods, to test the effectiveness of interventions (Pinfold, et al., 1988). The VRBG plates are used 'for the detection and enumeration of enterobacteriaceae' (International Organization for Standardization, 2004). The method was used due to the relatively low cost, which makes it suitable for low income scenarios. The quantification of the effect of different hand washing procedures on bacterial load is helpful for studies within a poor sanitation situation, where the environmental contamination with fecal organisms is high (Burton, et al., 2011, p. 101). The sampling and examination was done by *FAST Laboratory* in Manila, Philippines in February 2014, based on the 'Compendium of Methods for the Microbiological Examination of Foods' (American Public Health Association, 2001).

Often the glove juice method is used to take bacterial samples, which has been demonstrated to be the most accurate way to recover bacteria from hands. That method seems to be inappropriate for this study, due to higher costs. As well, the study does not claim to show exactly how many bacteria were removed from each arm, but more to compare the amount between the two arms.

To ensure a countable infection of enterobacteriaceae on finger pads, the volunteers were asked not to wash their hands within two hours before the trial and self-contamination exercise was performed. All participants walked the stairs in a public building up and down, while touching the handrails, after that they counted money, coins and notes, and touched a used sponge from a public kitchen. A similar practice was also used by Burton et al. (2011. p. 98).

All participants gave their samples with the fingers of their dominant hand, given the fact that this one has more germs than the other one (Alwis, et al., 2012, p. 3). The division between genders is necessary, because women have a greater diversity of germs on their hands (Fierer, et al., 2008, p. 17997).

The total number of bacteria transferred to VRBG hand-stamp plates was counted in colony forming units (CFU) directly from the agar plates by the laboratory. Raw CFU counts were converted to log_{10} values.

Data analysis and statistical considerations

The log_{10} reduction is determined by the number of e.coli bacteria present on the hands pre- and postwash. Several studies based on this methodology use the same method to estimate the efficiency of hand washing agents (Boyce & Pittet, 2002, p. 7; Kampf & Kramer, 2004, p. 871; Sickerbert-Bennett, et al., 2004, p. 70).

Log_{10} Reductions were compared to test the null-hypothesis that: *The use of a group hand washing station <u>does not have</u> a different effect on bacterial contamination of enterobacteriaceae on finger pads compared with individual hand washing station (H_0).*

The alternative hypothesis H_1 is: *The use of a group hand washing station <u>has</u> a different effect on bacterial contamination of enterobacteriaceae on finger pads compared with individual hand washing station.*

The individual reduction in each arm “a” (“*iHWWS: individual hand washing with soap” or “CM: Core Module”)* for each subject “*i*” (for i = 1,…,18) was given by: $R_{a,i} = log_{10}^{a\,before,i} - log_{10}^{a\,after,i}$

With the mean in the groups of $\mu_a = \frac{1}{18}\sum_{i=1}^{18} R_{a,i}$

Following the null hypothesis cannot be rejected, if $H_0: \mu_{iHWWS} = \mu_{CM}$.

A confidence interval with 95% is used to show the range of effect sizes. If the confidence interval embraces the value of no difference between the treatments, it indicates that the treatment under investigation (group hand washing at the Core Module) is not significantly different from the control (individual hand washing at a faucet).

Statistical comparison was performed by using paired t-test in Excel 2007, since the population can be assumed to be normally distributed.

Procedure

The figure below gives an overview of the trial procedure. The whole study population was divided in two groups with nine subjects. To avoid learning effects, the groups gave their test samples and crossed in the morning and in the afternoon, like figure 12 shows.

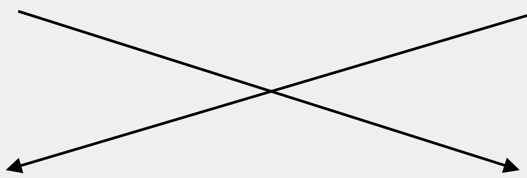
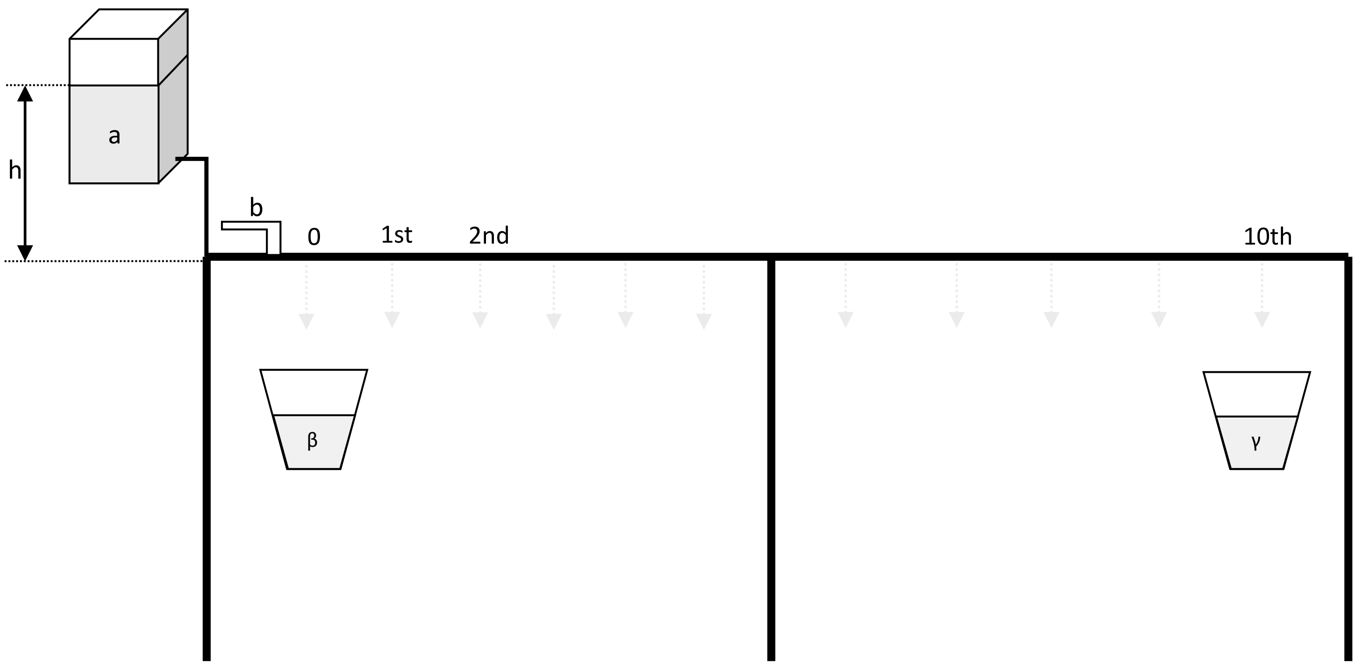
	Individual hand washing		**Group hand washing at Core Module**
Morning	Introduction hand washing skills, self-contamination		
	Sample of finger pads of dominant hand		
	Group 1 wash hands and give sample of dominant hand		
			Group 1 and 2 wash hands
			Group 2 give sample of dominant hand
			
Afternoon	Introduction hand washing skills, self-contamination		
	Sample of finger pads of dominant hand		
	Group 2 wash hands and give sample of dominant hand		
			Group 1 and 2 wash hands
			Group 1 give sample of dominant hand

Figure 13: Trial Procedure

Experimental Setup (Sketch)



a: Water bucket with 6625ml
b: Ball valve to open and close the water supply
Hydrostatic Pressure:
h= 94,5 cm
p(h)= ρ x g x h≈ 9270 $\frac{N}{m^2}$
= 0.0927 bar
Soap
Between each hole one piece of soap (45g) in hair nets
β: Amount of Water in bucket 1
γ : Amount of Water in bucket 2

Volunteer Position

Hole No		0	1	2	3	4	5	6	7	8	9	10
Volunteer No	Arm 1	x	1	2	3	4	5	6	7	8	9	x
	Arm 2	x	10	11	12	13	14	15	16	17	18	x

Figure 14: Experimental Setup

Technical Sector

This part of the thesis explains the methodology used to assess the technical functionality of the installed Core Modules directly at the Schools.

An assessment tool was designed to clarify the technical aspects of 100 Core Modules (N=100) installed by GIZ in the province of Iloilo, Philippines, at 50 Elementary Schools (M=50).

The assessment form was designed to evaluate the two aspects ‘construction’ and ‘usability’ in the technical sector. Construction aspects focus on the durability of used materials, quality of the processed goods and the management of water. The analysis of the water management indicators will be described later in this chapter. The durability of the materials indicates if the parts used in the design (e.g. GI pipes, garden hose and plastic bucket) are sustainable with an expected long life or if they or too weak to persist for a long time at a school. The process quality focuses on the way the producer handled the GI pipes and couplings, to clarify if the production quality is sufficient.

The *usability* indicator is evaluated by the satisfaction of the school community and the accessibility. The contentment was asked in a semi-structured interview and the accessibility was observed.

The indicators were designed to answer the question of whether the construction and usability of the facility is sufficient for the use of the Core Module in Primary Schools. Only if both aspects work out fine, the Core Module can be considered to be technically functional. The findings of the interviews and observations will help to improve the design of the Core Module, in line with to the needs and requirements of primary schools.

The assessment tool is separated in different parts:

1. Information on Interviewer and Main Interviewee (Principal)
2. School Information
3. Interview with the principal
4. Refilling Process
5. Core Module Assessment

Part one and two are important for the mapping of the schools, as well as future follow up visits. The interview (3) with the principal was semi-structured, to give the opportunity to find out the experiences with the Core Module at the school. To find out the opinion of different groups at the school, as well as to motivate the principal to speak out freely, he was asked to answer in the name of the students and parents. The answers given were clustered into five major statements (positive emotional, positive practical, neutral, negative practical and none). The interview was conducted in the regional language Hiligaynon, and directly translated to English.

After the interview, the principle was asked to show the interviewer how the bucket gets refilled (4). The observation of the process, the time needed and the distance to the source was noted by the interviewer.

For the mentioned parts (1-4) the collected data volume is 50, one per school.

At the end, the interviewer inspected all Core Modules at the schools with a check list, including the measurement of dimensions, check of the water flow and validation, and whether all items were in place and in good shape. The data set of this observation is 100, one per delivered Core Module.

The observation method is used to prevent a social desirability bias, which is the tendency for respondents to answer questions in a way which seems more socially acceptable. In that way, the study tries to combine the positive aspects of interviews and observations within one assessment tool.

The assessment form was carried out in February 2014 by students of the Central Philippine University (CPU), Iloilo City. At this point, all Core Modules had been at the school ground from one up to three months. The principles were informed beforehand about the visit. In some schools, the assessment was combined with the delivery of hygiene kits, due to logistical reasons.

Assessment population and sample size

The assessment examined 100 Core Modules in 50 elementary schools in 8 municipalities of the province of Iloilo. The schools that benefited by the installation were chosen in cooperation between DepEd and GIZ.

All schools were affected by the typhoon Haiyan, but many resumed to a daily school routine even if they did not have water or electricity. At nearly all schools, reconstruction activities were in action and in some schools international agencies were present to rebuild roofs or to arrange temporary learning tents. Taken all together, a healthy and productive learning environment was not given at the schools.

In total, 19,907 students are enrolled in the elementary schools, so the mean school population is 398 students per school [88 up to 1800]. The number of Core Modules delivered and installed per school differs from 1 up to 9 Core Modules, depending on the official number of enrolled students. A ration of 200 students per Core Module was proposed, but not reached every time in small schools. Figure 12 shows the number of distributed Core Modules, of schools and students per targeted municipality in the region of Iloilo. The production site of the Core Modules at ATC is in the south of the island in Iloilo City. Compared to the path of typhoon Haiyan (figure 10) it is obvious that the municipalities are directly in the corridor of destruction.

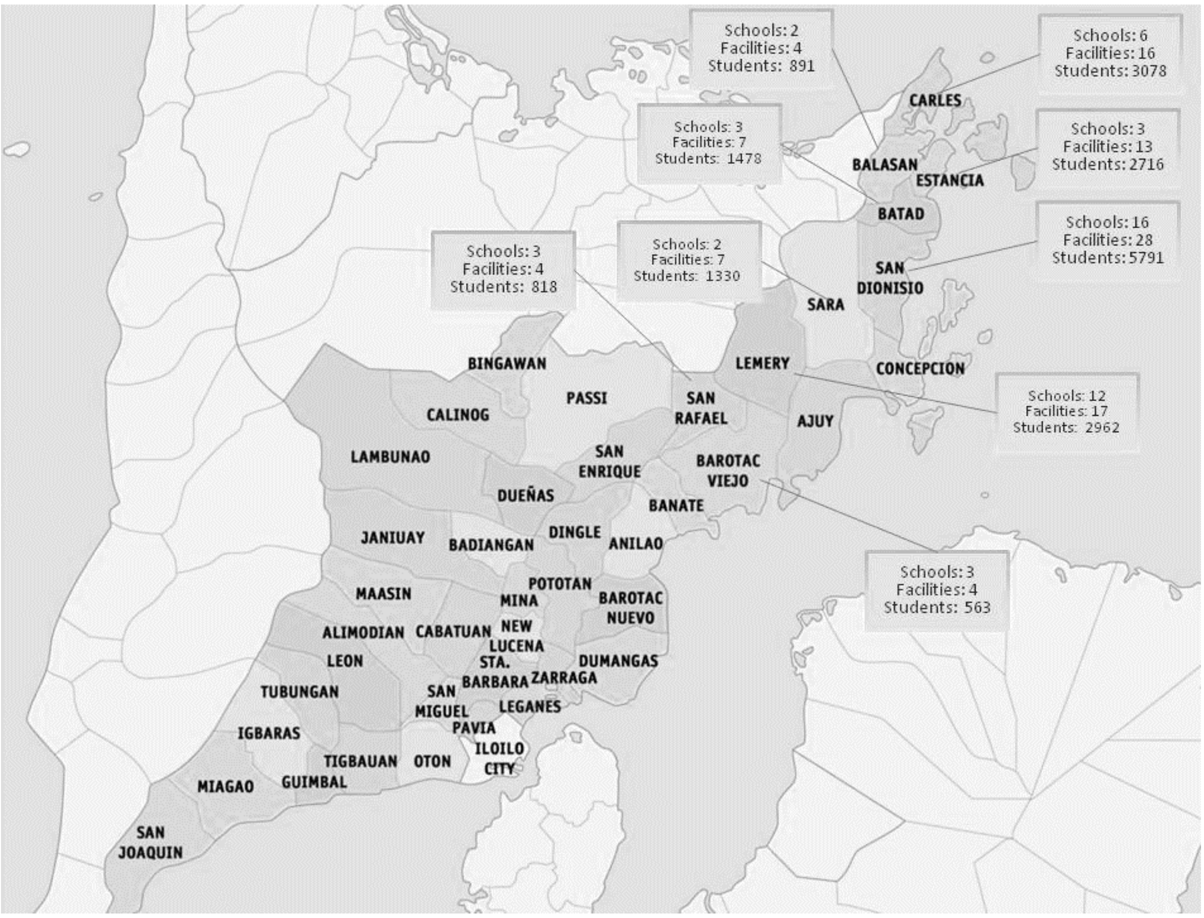


Figure 15: Target municipalities. Number of Core Modules, Students and Schools

Water Management

Since water treatment is an important topic in schools of low-income countries, this part is discussed separately. The water management indicator is divided in two parts: The *Enhancement* and the *Refilling Process.*

The Enhancement covers all structural changes of the Core Module, added by the school community. Enhancements can be beautification with paint, handling of waste water with a drainage system or a solution for sustainable elevation of the water bucket. Speaking generally, enhancement supports the environment of the Core Module and eliminates friction, e.g. by clarifying roles and facilitating the process. Both are principles which can support a behavior change, following Neal's (2014) two brain system approach, described in the background chapter. An enhancement ratio (ER; $0 \leq ER \leq 1$) was designed to demonstrate how many of the installed Core Modules at a school ground are enhanced and to make comparisons between different set ups and situations possible. The ER does not give any insights on the quality of enhancements, but on the quantity. The ratio is calculated by:

$$ER^m = \frac{N^m_{enhanced}}{N^m_{installed}} \quad \text{; with } N\text{: Number of facilities}$$

The 'm' describes different settings, for example, the school, municipality and gender of principal. A ratio of one would mean that all Core Modules in the observed setting are enhanced. Enhancements, however big or small, are hints as to whether the schools are willing to work with the Core Module and use it. The question is "Which kind of schools are more likely to enhance the facility?"

The *Refilling Process* concentrates on the organizational aspects within the school community, to find out how the schools organize the daily school routines. Different ways of activities could lead to different results. The study will highlight what organizational aspects are existing in schools.

Enumeration and Statistical Analyses

The assessment was carried out by staff of ATC, since they know the location of the schools and could also assist with minor repairs or give advice to improve the usability. The sheets were transcribed and organized in February 2014 with Microsoft Access 2010. The results were analyzed with Excel 2007. Based on the raw dataset the ER was calculated.

Figure 16: Field visit with assessment

A considerable bias in the study is the fact that all of the school communities were affected by the typhoon Haiyan, which may influence further activities, like constructing enhancements and beautifications for the Core Module by the school community.

Results

This section of the study presents the results, and implications for a redesign will be discussed later. Following the study structure, first the results of the microbiological hand washing trial will be shown. The results are organized in three parts: water consumption, microbiological germ reduction and efficiency.

Study Structure			
Main Question	Is the Core Module functional?		
Sectors	Microbiological	**Technical**	
Aspects	Hand hygiene	Construction	Usability
Indicators	• Germ reducing effect • Water Consumption • Efficiency	• Durability of Materials • Processing Quality • Water Management	• Satisfaction • Accessibility
Method	Microbiological Trial	Assessment Form	

Figure 17: Study Structure - Focus Microbiological

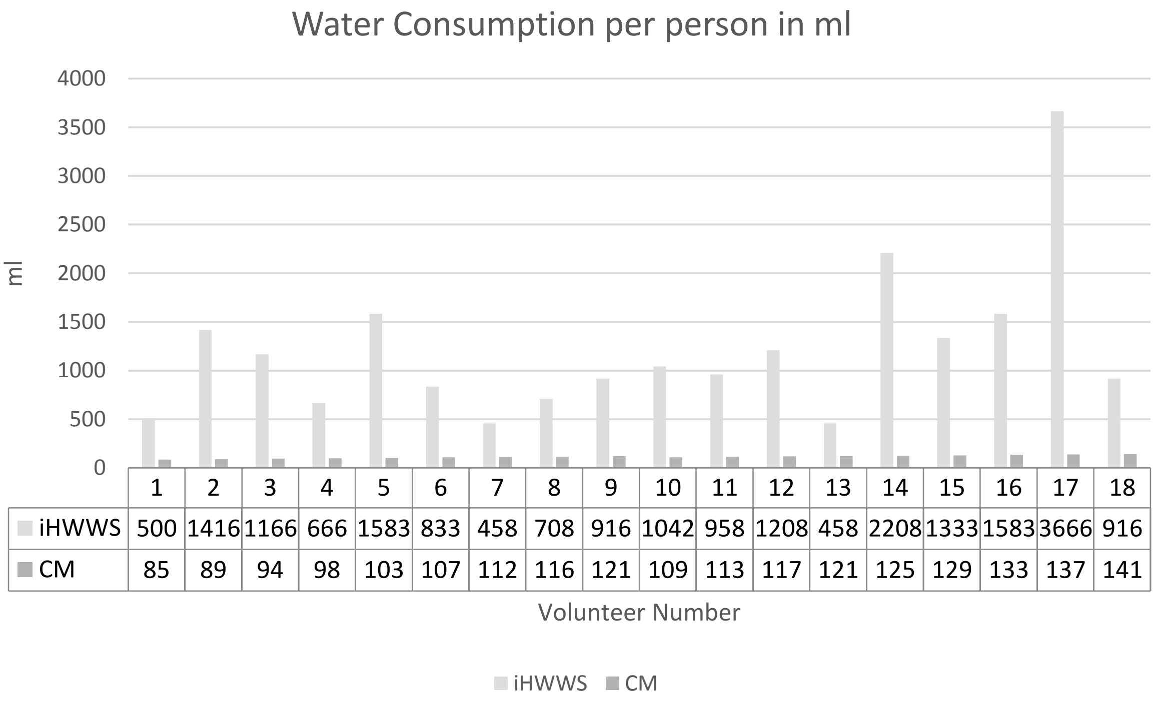
After showing the results of the hand washing trial, the figures of the technical assessment will be presented, divided into two aspects *Construction* and *Usability*.

Results: Microbiological Sector

Based on the need to consume only a little amount of water, the consumption of the Core Module is due the small boreholes, which use much less water than an individual faucet. The first part of the microbiological results will clarify how much water the Core Module used for a normal group procedure, in the next step it will be investigated if this amount is enough for hand washing with a germ reducing effect.

Water Consumption

As assumed, the water consumption varies substantially. The figure below shows the water consumption per person, with a mean of $\overline{Y_{iHHWS}} = 1201$ml and $\overline{Y_{CM}} = 114$ml. Individual hand washing at a faucet uses ten times more water than the Core Module.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
iHWWS	500	1416	1166	666	1583	833	458	708	916	1042	958	1208	458	2208	1333	1583	3666	916
CM	85	89	94	98	103	107	112	116	121	109	113	117	121	125	129	133	137	141

Figure 18: Water Consumption

The highest amount used for iHHWS was 3666ml, which is 26 times higher than the maximum value (141ml) of the Core Module. More water drops out at the last bore hole, due to a higher pressure at the end of the pipe.

Clearly, the Core Module uses less water than the normal faucet. The next step will clarify if this amount of water is enough to wash hands with the required germ reducing effect.

Germ Reducing Effect

As shown, the Core Module uses substantially less water than iHHWS with a standard faucet. However it is not clarified yet, how much water at a minimum level is needed to wash hands with a germ reducing effect (Shordt, 2006, p. 6). The target of this section is to answer whether there is a significant difference in germ reduction while using the two different hand washing interventions:

1. Individual Hand washing with soap (iHHWS) with a standard faucet
2. Hand washing with soap in a group activity with the *Core Module (CM)*

The methods used were described in detail in the section 'Methods'. In summary, Enterobacteriaceae colony-forming units (CFUs) were counted on VRGB agar plates, touched before and after hand washing procedure for both interventions by each of the 18 volunteers. A t-test for dependent means was used for testing the statistical significance.

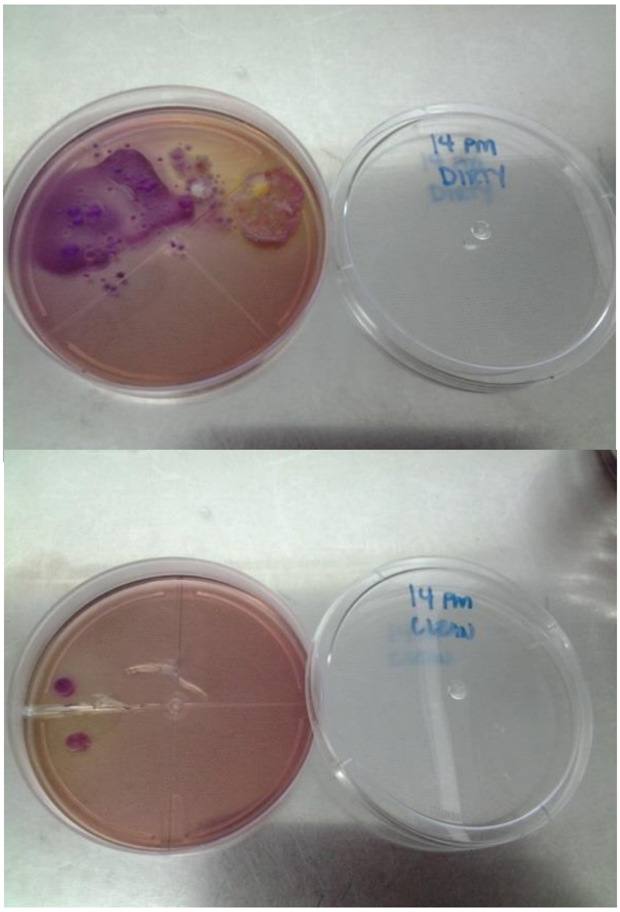
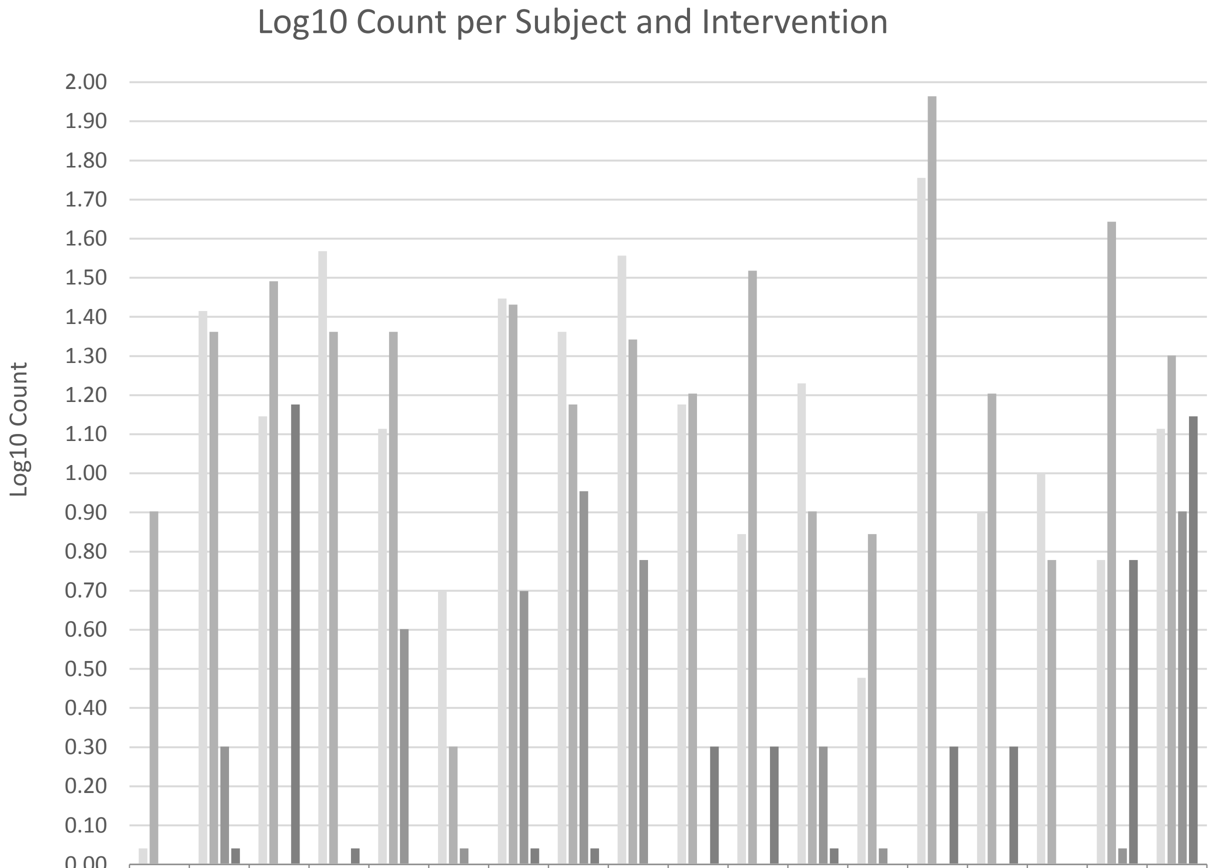


Figure 19: Germ contamination on finger prints on agar plate before and after hand washing at the Core Module

Absolute Figures

On the right side, figure 19 gives an example for the different contamination of enterobacteriaceae of finger prints on VRGB agar plates. Figure 18 shows the reduction in log_{10} for both interventions, pre and post handwashing.



Volunteer Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Initial CM	0.04	1.41	1.15	1.57	1.11	0.70	1.45	1.36	1.56	1.18	0.85	1.23	0.48	1.76	0.90	1.00	0.78	1.11
Initial iHWWS	0.90	1.36	1.49	1.36	1.36	0.30	1.43	1.18	1.34	1.20	1.52	0.90	0.85	1.96	1.20	0.78	1.64	1.30
Post CM	0.00	0.30	0.00	0.00	0.60	0.04	0.70	0.95	0.78	0.00	0.00	0.30	0.04	0.00	0.00	0.00	0.04	0.90
Post iHWWS	0.00	0.04	1.18	0.04	0.00	0.00	0.04	0.04	0.00	0.30	0.30	0.04	0.00	0.30	0.30	0.00	0.78	1.15

Figure 20: Log10 Count per Subject and Intervention

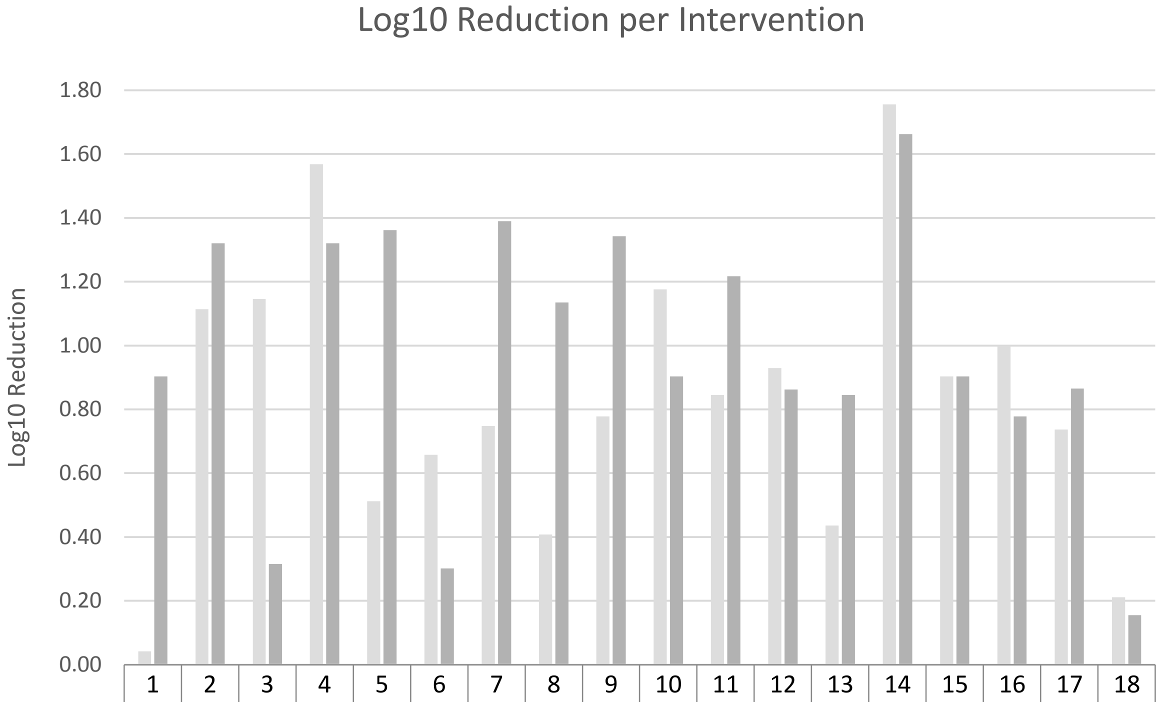
The maximum initial log_{10} was 1.96 in the iHHWS-Arm and 1.76 in the CM-Arm (both Volunteer 14). After hand washing, the maximum count was 1.15 for the iHWWS-arm and 0.95 for the Core Module-arm (Volunteer 17 and Volunteer 8). The minimum initial count was 0.04 for subject 1.

In each intervention for 11 people, no Enterobacteriaceae units were found at all ($log_{10} = 0$) after hand washing, but only 5 people have in both interventions no contamination of Enterobacteriaceae on the hands after cleansing.

Reduction

As described in the methods, the individual reduction in each arm "a" ("*iHWWS" or "CM")* for each subject "*i"* (for i = 1,…,18) is given by: $R_{a,i} = log_{10}^{a\,before,i} - log_{10}^{a\,after,i}$

The reduction in log_{10}per volunteer in each arm is shown in figure 21.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
CM	0.04	1.11	1.15	1.57	0.51	0.66	0.75	0.41	0.78	1.18	0.85	0.93	0.44	1.76	0.90	1.00	0.74	0.21
iHHWS	0.90	1.32	0.32	1.32	1.36	0.30	1.39	1.13	1.34	0.90	1.22	0.86	0.85	1.66	0.90	0.78	0.87	0.15

Figure 21: Log10 Reduction in per Intervention

The minimum reduction at the CM is 0.04, for subject number 1. For the same subject, also an initial 0.04 was measured, showing that the hands are germ free. The maximum reduction is 1.76. In the individual hand washing arm, the minimum reduction is 0.15, the maximum is 1.66.

For ten people, the reduction was greater at the individual procedure, for seven volunteers it was greater at the Core Module, for one person there was no difference measurable.

Female volunteers reduce the germs better in the iHHWS intervention than at the Core Module (1.00 to 0.71), the log_{10} reduction for male persons is equals in both arms (0.95). The male average over both arms is 0.95 higher than the female average of 0.85.

The average reduction for iHWWS is 0.99 log_{10}, while for CM it is 0.84 log_{10}.

The interpretation of the log_{10} reduction counts will be part of the chapter "Microbiological Discussion". Now it will be clarified if the difference in log_{10}reduction counts is significant or not.

Significance of Differences

Utilizing the paired t-test, the H_0("*There is no difference in the interventions*") cannot be rejected. The two tailed P value equals 0.21 and is not smaller than α=0.05. By conventional criteria, the difference is considered to be not statistically significant. The required precondition of a paired t-test is given, the differences are normally distributed.

For $R_{iHWWS,\ i} - R_{CM,\ i}$ the confidence interval at the level of 95% is [-0.09 – 0.38]. The interval embraces the value 0, which also indicates that there is no difference in the intervention. Figure 22 shows the confidence interval.

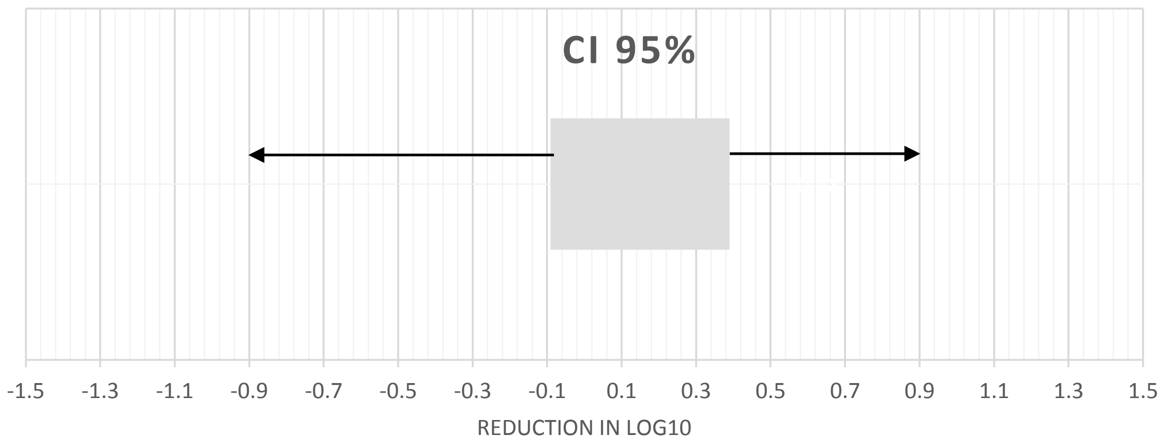
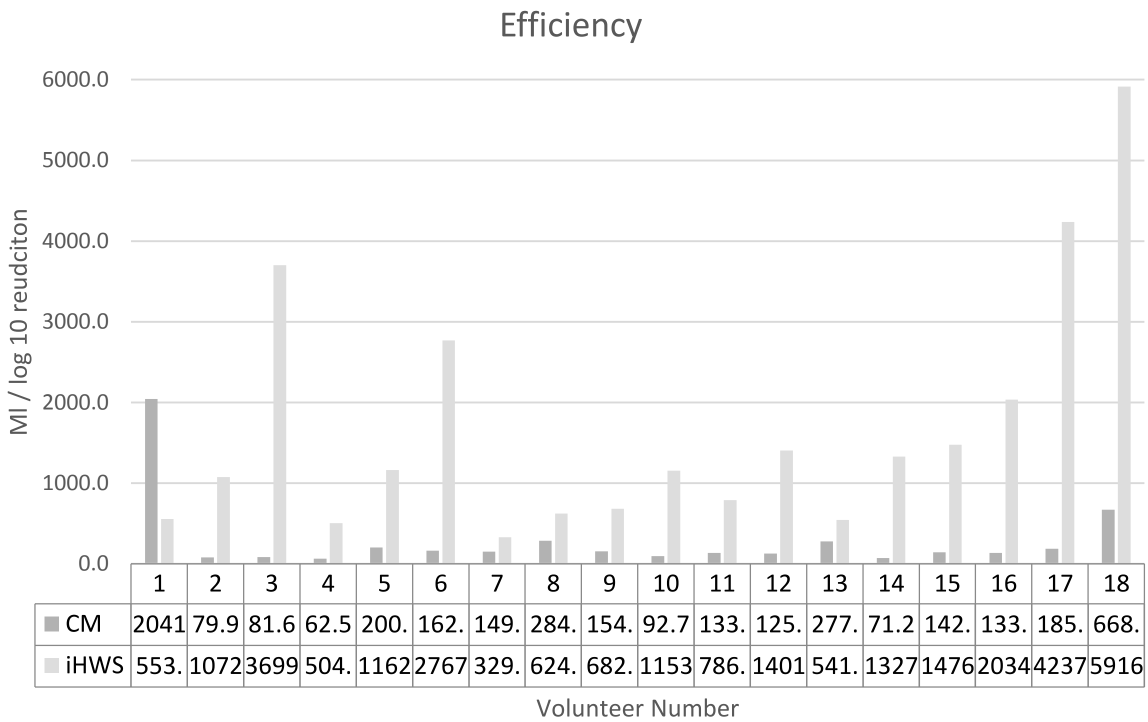


Figure 22: Confidence Interval

Efficiency

The efficiency is the ratio of the effect (germ reduction) to the total input, here the amount of water used to wash hands at the Core Module (CM) or at an individual hand washing faucet. Consequently, a low score can be considered to be more efficient than a higher score. Figure 27 gives an overview of all scores.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
CM	2041	79.9	81.6	62.5	200.	162.	149.	284.	154.	92.7	133.	125.	277.	71.2	142.	133.	185.	668.
iHWS	553.	1072	3699	504.	1162	2767	329.	624.	682.	1153	786.	1401	541.	1327	1476	2034	4237	5916

Figure 23: Efficiency of interventions

A high score can be caused by an extreme small log_{10} reduction, like in the Core Module arm of volunteer number 1 (0.04 log_{10}), or by a high consumption of water, like for volunteer number 17 with more than 3.6 liters.

The efficiency of the Core Module differs from 62.5$\frac{ml}{Log_{10}}$ to 280.5$\frac{ml}{Log_{10}}$. The range at the individual faucet is between 329.5 and 5916.0. The average at the Core Module is 280.5$\frac{ml}{Log_{10}}$ at the faucet it is 1681.9$\frac{ml}{Log_{10}}$. The efficiency at group hand washing is six times greater than at an individual faucet.

The increased efficiency can be useful for several situations and will be part of the discussion chapter.

Results: Technical Sector

After the microbiological trial clarified the microbiological capability of the Core Module and demonstrated that there is no significant difference in the reduction of bacterial contamination of hands by using the Core Module or performing individual hand washing at a standard faucet, the next urgent question is how the facilities are used in the field.

After the installation of the Core Module, an ATC Team returned to the schools to carry out an assessment form to monitor the functionality of the system. As mentioned in the methodology chapter, 100 Core Modules were assessed in 50 schools. The results will be used for the EDP to evaluate the existing Core Module.

Figure 23 shows again the study structure.

Study Structure			
Main Question	Is the Core Module functional?		
Sectors	Microbiological	**Technical**	
Aspects	Hand hygiene	Construction	Usability
Indicators	• Germ reducing effect • Water Consumption • Efficiency	• Durability of Materials • Processing Quality • Water Management	• Satisfaction • Accessibility
Method	Microbiological Trial	Assessment Form	

Figure 24: Study Structure - Focus Technical Sector

The figure above shows again the study structure and highlights the *Technical* Sector. The Assessment Form was designed to clarify *Construction* and *Usability* aspects, as described in the Methodologies. First, construction aspects will be highlighted, then usability aspects.

In total, 96 out of 100 Core Modules were installed in schools at the time of the assessment; four Core Modules were not installed, but temporarily stored due to rebuilding activities at the school ground. In 49 out of 50 schools, at least one facility was installed. The 96 Core Modules are the base for following calculations.

Construction Aspects

As described earlier, the indicators for the construction aspects are the durability of materials, the process quality on the one hand, and on the other hand the water management, which includes structural enhancements and the refilling process.

Durability of Materials and Processing Quality

The process quality describes the level of accuracy of the prefabrication process. As described in the background chapter, the prefabrication includes cutting, drilling, threading and assembling. The durability of materials is the live experience of used mechanical components, like the ball valve, tee junction and union connections.

None of the GI pipes were observed to be broken at the Core Modules in the schools, also 100% of the ball valves were functional and not broken. But 14% of the faucets for individual hand washing were partly broken or fully apart. At 82% of all observed Core Modules, there was no leaking at the connection between garden hose and facility, but more than half (52%) of the Core Modules have no waterproof connection to the water bucket.

The connection between the posts and the water pipe with the union connection was functioning in 91% of all Core Modules and 99% of the posts were fixed in the ground properly.

At 7 facilities problems occurred, due to congested bore holes at the water pipe. Sediments of sand and algae were responsible for the plugging.

Water Management

As mentioned earlier in the background chapter, the importance of water management is a topic of increased interest within school communities. All facilities were delivered to the schools with a 5 Gallon water tank. Water management is defined in this study as the supply to the Core Module and the disposal of water after usage. For the water management, two aspects are important: structural enhancements and the refilling process.

Structural Enhancement

The Core Module design leaves space for enhancements to be created by the school community itself. An enhancement planned, budgeted and implemented by school communities supports the concept of ownership of the facility. It also proves the willingness to use and maintain the Core Module.

In this chapter “structural enhancement” is defined by any kind of add-ons constructed by the school community itself. The add-ons can be low cost and simple, like a gravel bed, or expansive like a sink with tiles. Also structural, permanent solutions for the water supply are enhancements.

The initial task to enhance the installation of the Core Module for the school, was to elevate the bucket to ensure hydrostatic pressure. Only one fifth (23%) of all Core Modules were operated at the time of the assessment with no permanent solution to elevate the bucket, it was simply elevated by somebody. Nearly the same percentage (22%) of facilities worked with a bucket attached to the existing infrastructure at the roof or the building. 10% of the Core Modules were attached to the pipe system of the school; another 10% elevated the bucket at a tree. Most schools decided to build a rack (35%) to ensure sufficient water pressure.

Also, a basin is no precondition for the functionality of the Core Module, yet some schools constructed a sink. A sink is used to keep the soil dry and avoid splashes at the feet of the students. 6% of all Core Modules had a massive construction out of tiles, concrete or PVC pipes, 13% put flower pods under the facility. The most common way to handle the waste water was simply the soil absorption (86%) without a massive construction, a gravel bed or a connection to an existing drainage system are both used by 5% of all Core Modules installed. Also, portable drain receptacles are used (3%) to water the plants with the grey water.

Figure 24 on the next page shows some example pictures of enhancements.

Enhancement			
			
Bolo Elementary School (ES)	**Muyco ES**	**San Fernando ES**	**Tanao ES**
Concrete basin with tiles. Water supply with five gallon bucket, disposal of waste water with a portable drain receptacle.	Water supply with bucket, which is attached to a tree. Waste water collection over a halved PVC pipe with soil absorption.	Water supply with drum on a metal rack. Waste water collection with a concrete basin with final disposal to existing drainage system	The bucket is connected to the school building, natural slope is utilized. No basin is used, and the waste water is absorbed directly under the Core Module in the gravel bed.

Figure 25: Enhancement examples

As mentioned earlier, enhancements are hints that schools are willing to use and maintain the Core Module. The question is: "What kind of setting at a school (community) is important to make an enhancement of the Core Module more likely?"

In total, 68 out of 96 Core Modules have some kind of enhancement. An enhancement ratio (ER; 0 ≤ ER ≤1) was designed to demonstrate how many of the installed facilities at a school ground are enhanced.

The overall average ER is 0.75 for all installed Core Modules, meaning three-quarters of all Core Modules have some kind of enhancement as described earlier. The following the ER is analyzed in regard to different settings and circumstances, the results are shown in table 4-8. For a better understanding, the total number of schools are also listed.

First it will be analyzed to see if there is a link between the numbers of Core Modules installed at a school and the prevalence of an enhancement.

Number of Core Modules at Schools	Average ER	Total Number of schools
1	0,86	21
2	0,63	19
3	0,80	5
4	0,88	2
5	0	1
9	0,78	1

Table 4: Number of Core Modules at Schools

The range of the average ER differs from 0.63 up to 0.88, excluding one school with five facilities and no enhancement. With a coefficient of determination (R^2), in a linear regression, $R^2=0.02$ there is no link between the number of installed facilities at a school and the number of enhanced ones.

The gender of the principal could also have an influence of enhancements.

Gender of Principal	Average ER	Total Number of schools
Female	0,69	35
Male	0,89	14

Table 5: Gender of Principal

There is a higher chance for established add-ons in schools with a male principal, than in a school with a female director.

All Core Modules were installed in the nine municipalities of Iloilo province. A possible correlation between the municipality and ER is analyzed in the table below.

Municipality	Average ER	Total Number of schools
Balasan	0,5	2
Sara	0,25	2
Barotac Viejo	1	3
Batad	0,5	3
Estancia	0,77	3
San Rafael	1	3
Carles	0,83	6
Lemery	0,9	11
San Dionisio	0,73	16

Table 6: Number of Core Modules per Municipality

Considering all municipalities, there is with R^2=0.17 only a small link between the number of schools in a municipality and the possibility for enhancements. Calculating the maximum and minimum out (2 schools and 16 schools) there is a strong positive coefficient of determination R^2=0.97. Also there obviously is a large range between 0.25 and 1.00 ER within the nine municipalities.

In the interview part of the assessment, the principals were asked how content they are with the Core Module. The results of the interview will be discussed in detail later. Most of the school directors were pleased with the facility, only three schools were not or only partly satisfied.

Content with Core Module?	Average ER	Total Number of schools
Yes	0,72	46
Particularly	1,00	2
No	1,00	1

Table 7: Contentment with Core Module

The contentment of the principals does not positively influence the construction of enhancements.

A national partner organization of GIZ carried out orientations about the EHCP Approach to all schools. These orientation workshops give the schools a broader picture about the reasons why they could benefit from group activities within their school and it motivates the principals and teachers to conduct daily group hygiene activities with the students. A possible relation between the knowledge of benefits and the enhancement of the group washing facility is pointed out in the table below.

Received EHCP Orientation?	Average ER	Total Number of schools
Yes	0,76	38
No	0,53	8

Table 8: EHCP Orientation

The different is more than 0.20ER points for schools with knowledge about the benefits of group washing activities.

Refilling Process

The observation of the refilling process gives a chance to gather information on how the community refill the bucket and what are the circumstances that promote a filled bucket, to make the Core Module operational.

The interviewer observed at first the filling level of the connected bucket of all Core Modules. The observation of the filling level can be an indicator whether or not the schools are using the facility frequently - if the bucket is totally empty, the assumption is that the facility is not used at all.

In total, 89 buckets were observed, because ten Core Modules have pipe water supply. The average filling of the observed ones was 44%, so 2.2 Gallons. 37 receptacles were totally empty, 29 were brimmed. As mentioned above, there were several ways to elevate the container: Attachment to the roof, building (1) or tree (2), a rack (3) or somebody simply elevates the bucket (4). Table 9 gives an overview of results regarding the supply of water. For completeness, also water pipe connection is included in the overview on the next page.

	Solution to elevate the water bucket	Used for % Core Modules	% Filling of the bucket	Average Altitude in cm
1	Attached to roof/building	22%	62%	159
2	Attached to tree	9%	42%	167
3	Rack	35%	36%	164
4	Somebody elevates the bucket. No fix installation	23%	40%	nA
5	Water pipe	10%	nA	nA

Table 9: Elevation of bucket

Assorted by the percentage filling, the best solution is to attach the bucket at a roof or building (62% filling), which has also the lowest average altitude, followed by an attachment to a tree with 42% and a non-permanent solution with 40%. The worst solution is a rack 36%.

Another part of the assessment was to observe the refilling process for one Core Module at each school. One school did not have at least one facility installed and 6 schools connected their Core Modules to an existing water pipe system, so 43 refilling processes were observed and documented.

The main questions of the refilling process are:

- Who is responsible for the refilling?
- How much time is needed?
- How far away is the water source?
- How successful is the process?

To answer the last question, the percentage filling of the buckets at schools will be taken as a benchmark. An average filling rank per school was formed, assuming that the procedures and responsibilities were similar within the school for the other installed Core Modules.

In all 43 schools, the students are responsible for the refilling of the bucket, in two schools they get assistance by the guard, in one school by a teacher, in another one by parents. The average filling of the water tanks in schools where only students were responsible for refilling was 50%, the best average filling level was in schools where guards and students work together (66,5%), the less successful process was in the school where parents participate in the activity (25%).

In nearly all schools, the refilling is organized in a group activity, only in two schools one student is refilling the bucket on his own. 18 schools work with a team of two students, ten schools with three and four schools with four students. The most successful way, in terms of average filling of the buckets is a group of 4 students (87%), followed by a three man team (53%).

In 67%, the distance between the facility and the water source is 1 up to 20 meters. The average filling is between 11-20 meters lower than 91-100 meters (65% to 88%).

The refilling process takes less than 5 minutes in 67% of all schools, and less than 10 minutes in 90%. The required time of course is connected to the distance to the water source as well as to the way the schools organize their activities.

Usability Aspects

The second aspect of the technical sector is the usability. This aspect highlights the suitability and appropriacy of the Core Module at a school setting. It covers design aspects like dimensions, accessibility and first user. Part of the assessment tool was a semi-structured interview with the principal to spot the convenience of different stakeholders, as well as observed problems or suggestions for improvements.

Convenience

At first the principle was asked if she/he is content with the Core Module. 94% answered the question with ‘Yes’, only one school is not satisfied and two schools only particularly. Both of the “Particular Content” schools criticized the size of the water bucket; 5 gallons would not be big enough to ensure group wash activities for the calculated 200 students per facility.

In total, 23 schools complain about the bucket, based on three reasons mentioned during the interview:

1. Size of bucket
2. Refilling Process
3. Elevation

The delivered 5 gallon tank has a narrow opening which makes the refilling harder, especially when the bucket is elevated. The elevation of the bucket poses a challenge to some schools, as also found in the number of not elevated buckets in the "Construction Aspects" above.

Two schools mentioned that they do not like the faucet; another two schools dislike the garden hose connection between bucket and Core Module and the location at the school ground where the facility has been installed.

Asking the principle for positive things about the Core Module, 60% mentioned the positive aspects of group activities, 24% the durable materials and set up and 35% like the easy use of the Core Module.

The principle was asked to give feedback in the name of the students, teachers and parents. The answers were clustered and are shown in table ten.

Feedback	Students	Teachers	Parents
Positive emotional	34	26	24
Positive practical	2	5	3
Neutral	5	11	13
Negative practical	4	3	0
none	4	4	9

Table 10: Feedback

From all stakeholders, the emotional benefit is mentioned most, followed by a neutral feedback. The practical benefit is mostly seen by teachers and the emotional benefit mostly by students. A neutral or non-feedback comes from the parents of 21 schools. The negative feedback by students in four schools is based on the size and placement of the bucket and the refilling process. The negative response by teachers is attributed to the faucet and also the refilling process. The positive emotional feedback by students is based on mentioned attributes like "enjoy, happy, excited, thankful and curious", the teachers have a wider, less emotional view and mention that the facility is "helpful for the school".

Accessibility

To benefit completely from the system capabilities, it is necessary to ensure that students can access the Core Module from both sides; otherwise only 11 students can wash their hands or brush their teeth at the same time. 68% of the 96 Core Modules were installed in a way that makes a usage from both sides possible, in 32% only a use from one side is possible in the encountered situation.

The average height of the water pipe is 132 cm, measured from the ground; the minimum is 103 cm, the maximum is 180 cm. However, an altitude of 110 cm was initially planned.

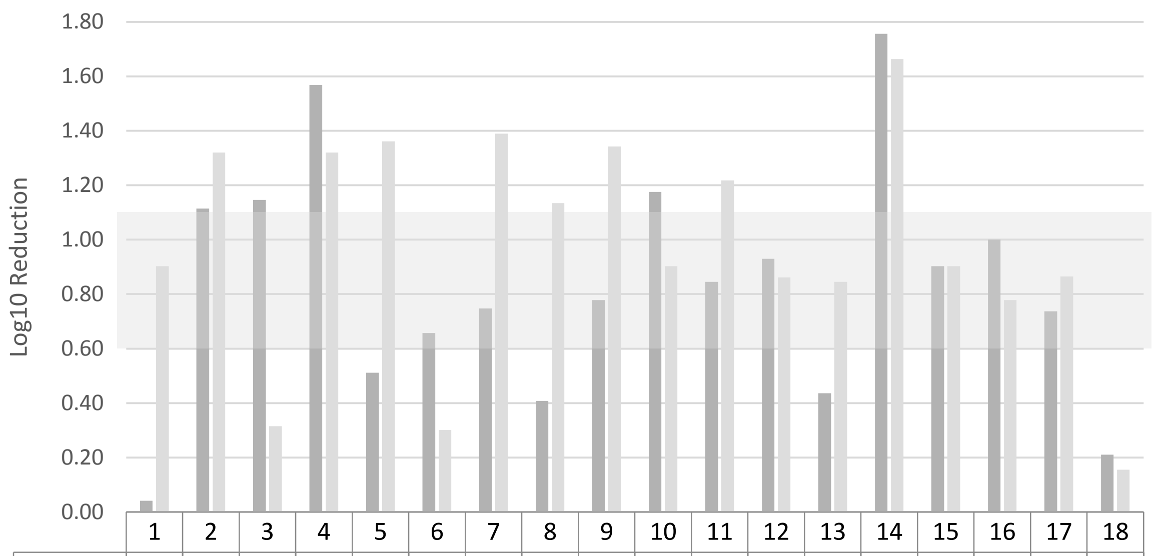
Discussion

The objective of the study is to investigate whether the Core Module is already a scalable solution to promote personal hygiene activities in primary schools, or what steps need to be taken to develop a design in regards to upscaling to other schools, countries and regions. To give an answer, the study was separated in two sectors: The technical performance and microbiological effectiveness. To examine the technical sustainability, an assessment was carried out in 50 schools in the Philippines. To clarify if the Core Module is as effective as ordinary hand washing techniques to reduce bacteria load on hand skin surface, a microbiological test was conducted. The discussion will start with the microbiological results, followed by the technical insights.

Microbiological Discussion

The raw data of the microbiological trials show that there are differences in reduction achievements for each intervention and subject. On average, the individual hand washing is slightly better than the group activity at the Core Module. The mean reduction for iHWWS was 0.99log_{10}, while for group hand washing it is 0.84log_{10}. The statistical analysis confirmed that these differences are not significant, so the Core Module works as good as an individual faucet in reducing germ load on the surface of hands.

Taking a look at other studies, it is obvious that the results are comparable. In 1999, Rotter observed a reduction range of 0.6 - 1.1 log_{10}, for hand washing with plain soap (Rotter, 1999).

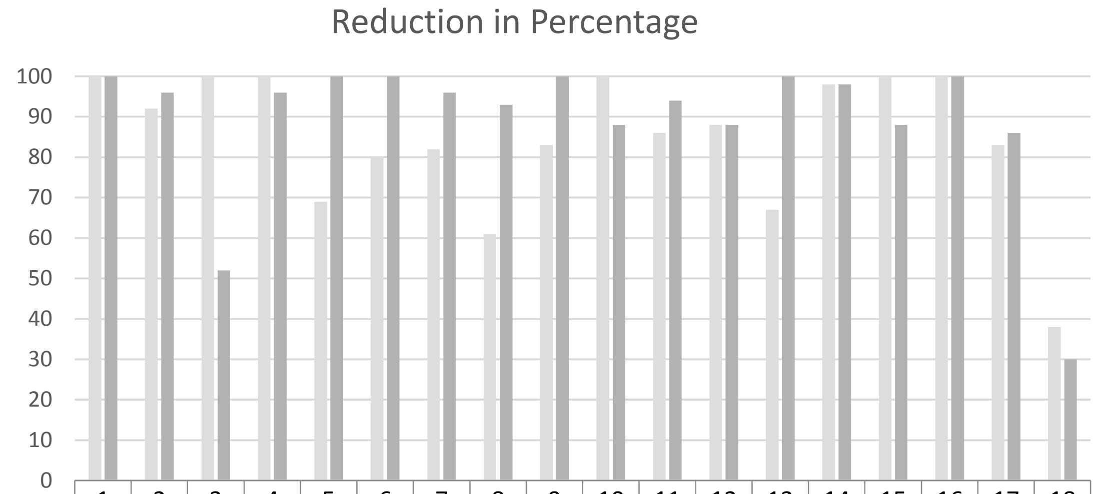


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
CM	0.04	1.11	1.15	1.57	0.51	0.66	0.75	0.41	0.78	1.18	0.85	0.93	0.44	1.76	0.90	1.00	0.74	0.21
iHHWS	0.90	1.32	0.32	1.32	1.36	0.30	1.39	1.13	1.34	0.90	1.22	0.86	0.85	1.66	0.90	0.78	0.87	0.15

Figure 26: Comparison of Log10 Reduction

Given that as a normal margin (grey box) and taking a look again at the log_{10} reduction figure, it is clear that some results are under or over the margin. Figure 25 shows that 3 out of 18 subjects underperformed at the individual faucet whereas eight were better at the individual faucet, four underperformed at the Core Module and four over performed. Only subject number 18, a male volunteer, underperformed in both arms. This volunteer had an initial log_{10}1.11 (CM) and 1.30 (iHWWS), high enough values to possibly reach the lower reduction value of 0.6. Other subjects had already the initial log_{10} count a lower value than 0.6. For example, volunteer number one with 0.04 and number 13 with 0.48 at the Core Module, or number six with 0.30 in the individual procedure.

Scientific studies have not established a degree to which count of bacteria on hands need to be minimized to reduce the transmission of pathogens (Boyce & Pittet, 2002, p. 8). This demonstrates the limitations of analyzing data with the log_{10} reduction method. Another way to compare the results is the reduction in percentage, as shown in figure 21.



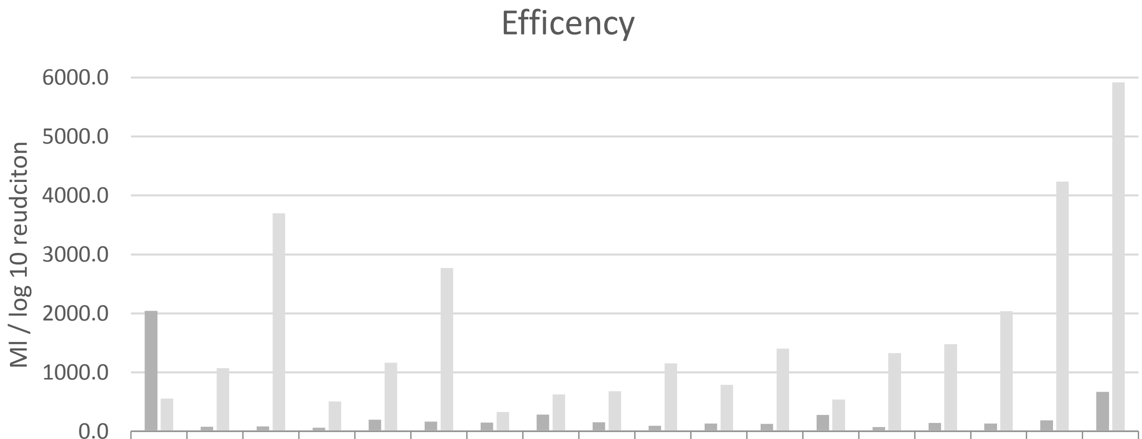
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
CM	100	92	100	100	69	80	82	61	83	100	86	88	67	98	100	100	83	38
iHWWS	100	96	52	96	100	100	96	93	100	88	94	88	100	98	88	100	86	30

Figure 27: Reduction in Percentage

The average reduction is 85% (CM) and 89% (iHWWS). Now it is clear that 6 out of the 18 volunteers had no Enterobacteriaceae CFU on their hands after performing hand washing at a faucet, as well as at the Core Module.

The Core Module works as well as a faucet. A great difference within the two procedures is the consumption of water.

As shown earlier, the efficiency of the group activity at the Core Module is six times higher than the individual hand washing, due to the reduced amount of water.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
CM	2041	79.9	81.6	62.5	200.	162.	149.	284.	154.	92.7	133.	125.	277.	71.2	142.	133.	185.	668.
iHWS	553.	1072	3699	504.	1162	2767	329.	624.	682.	1153	786.	1401	541.	1327	1476	2034	4237	5916

Figure 28: Efficiency of interventions

This is because of the controlled water supply and the design of the Core Module. At the faucet, each subject decides on their own when to open or close the tap. In addition the water pressure depends on the pressure in the pipe system and can be considered to be higher. This leads to a higher water consumption.

In the group activity at the Core Module, a supervisor opens the ball valve and all participants wet and rinse their hands at the same time. Also, as mentioned before, the bore holes are 1.5mm, which is very small, and only a little amount of water drops out.

As mentioned in the background, the availability of water is often not given in development countries. A study in Cambodia assessed that only 58% of schools have access to an improved water source (UNICEF, 2014), and even then access does not ensure the daily availability of water, since there can be problems with the water pressure in the pipes, due to non-functioning pumps, leakage and other problems.

In their guidelines, The World Food Program, World Health Organization and UNESCO set the minimum amount of water per schoolchild each day at 5 liters. The 5 liters 'include water use for drinking, hand hygiene cleaning and […] food preparation and laundry.' (Adams, et al., 2009, p. 19). So if the Core Module uses 6 times less water than a standard faucet, the amount of water for other mentioned activities would increase without any more efforts.

Not only in the daily school context is a minimized water consumption desirable. Also in post catastrophic scenarios, a water saving hand hygiene technique can be useful. The *Sphere Project*, a voluntary initiative with the aim to improve humanitarian assistance, defines two up to six liters, depending on cultural norms, as a minimum amount of water needed in humanitarian response (The Sphere Project, 2014).

The project also highlights the importance of waiting times at water points. It is very likely that people will not wash their hands if there are long queues. The volunteers needed 90 seconds (including wetting, scrubbing, rinsing) at the Core Module to wash hands, assuming this is the same time an individual procedure would take, so only after 33 minutes all people would have washed their hands.

If public pipe systems are used in schools or elsewhere, the resource water is also a pool of costs, so it is essential to use it sustainably. Table 11 compares the cost of both hand washing techniques based on the water quantity results of the study and the water prices in Iloilo in 2013.

	iHWWS	Core Module
Water consumption (average)	$1200ml \times 200 =$ 240 litre	$114ml \times 200 =$ 22,8 Litre
Cost for water in Iloilo[1]	$240\ litre \times 0{,}0159\ PHP =$ 3,82 PHP (per day) 1146 PHP / 26,10 US$ (per School Year)	$22{,}8\ litre \times 0{,}0159\ PHP =$ 0,36 PHP (per day) 108 PHP / 2,46 US$ (per School Year)

Table 11: Water costs in Iloilo

A school community can save around 24 US$ per year. This is around half of the annual funds for WASH activities in Cambodian schools (Shantz, 2013, p. 17). With material costs of 60 US$ for one Core Module, the investment is amortized after 30 months. The low investment costs can motivate political decision makers to invest in this technique, to reduce the burden of mortality in development countries (Aiello & Larson, 2002, p. 1).

[1] 15.90PHP per cubic meter (Pendon, 2013)

Limitations: Microbiological Assessment

The study was designed to get a realistic picture as to what extent the Core Module reduces germs on hands for group hand washing. So it was important that the procedure was performed in a group and not alone. This, and the need to quantify the amount of water used, was the limiting factor for the small study population. Data from small groups are more likely to lend to outliers, which occurred in the trial, and this can influence statistical analysis, for example the confidence interval.

The finger pad sampling method on an agar plate might be less accurate than the "glove juice" method, which assesses the microbiological load on the whole hand including the back and the area around the nail, but it is faster and cheaper, and also less equipment is needed (Hansen & Knochel, 2002, p. 484).

Fecal streptococci could be a good test objective for future tests in less controlled settings (no self-contamination), because of the relatively short living time of E.coli bacteria on the skin (Kaltenthaler & Pinfold, 1998, p. 102). Another agar plate would be needed then.

Due to the different sizes of finger pads and the variance of self-contamination, the variance of the initial germ load in both arms is big, which complicates a comparison of the arms, but it also reflects realistic circumstances and was done in similar ways in other studies (Pittet & et al, 1999, p. 1). Other studies, for example in Thailand, also used the finger print method to demonstrate that a simple microbiological test can be applied to groups in relatively short time. The same test design could be useful for future studies to assess and observe the microbiological reduction of the Core Module in schools, or to distinguish those who wash hands, from those who do not (Pinfold & Horan, 1996, p. 368).

Technical Discussion

The discussion about the results of the technical sector are based on the findings of the assessment of the installed Core Modules. The discussion highlights what is working well, and what need to be revised for an improved design.

Seeing the results of the assessment, it is important to keep in mind that the assessed Core Modules are in schools in a post catastrophe area, where often the whole school building was destroyed. Yet, the results of the assessment are useful to evaluate and redesign the Core Module for further improvements. Based on the earlier introduced EDP approach, the findings will lead to a new design of the Core Module. The results will be discussed separately within the *Construction* and *Usability* aspects and finally merged to a new design.

The assessment showed problems especially with the water bucket and the faucet for individual hand washing. Also, more adequate dimensions and other usability aspects need to be considered in the future.

Material and Process Quality

Important for the indicator “materials and processing” is the durability of the used materials and the process quality. The results give strong evidence that the **connection from the water tank** to the facility needs to be reconsidered (18% leaking at connection from garden hose to facility and 52% leaking at connection from bucket to garden hose). The faucet at the water tank is not tightly fitted to the bucket, so the faucet is an inappropriate solution.

The flexible garden hose gives a great chance for schools to elevate the bucket in a suitable way in each school setting, but it also poses problems. At one end the garden hose is connected with a thread connection to a plastic faucet of the water bucket, the other end is pulled over a ½ inch GI nipple. The solutions are functional, but not appropriate for a use in a school for a long time. If the bucket gets moved during the refilling or hand washing procedure, the flexible garden hose can become taut and wears out more quickly. Also, the long term influence of UV light and heat on the rubber of the garden hose may lead to flaws and cracks.

As a consequence, it is necessary to replace the garden hose as a connector between the water tank and the facility. To ensure a tight, waterproof fitting and durability also under extreme weather conditions, the use of GI pipes and couplings seem to be the best choice for a redesign of the Core Module. This allows for also excluding the faucet at the water tanks, which often is the source of leaking. A connection to the water tank with a bulkhead is the better, more stable solution.

The **process quality** of the cut threads was high, as well as the drilled bore holes, since no problems occurred. This is a sign of good handling by the producer ATC as well as a hint for high material quality. Without a high quality standard for the GI pipes, like DIN, it is more likely that the process quality drops and the threads get more inexact, frayed and leaky. A waterproof connection between the pipes and the junction part would not be possible anymore.

The leaking **union connection** in 9% of all assessed facilities is most probably the result of an inadequate installation at the school ground. If the connection is not fully closed and tight, or Teflon tape is not used or misused, there will be leaking. But also a defected element could be possible. However, the usage of the union connections is essential for the Core Module. Other possible solutions with solid connection parts, like a tee or an elbow, would require a radial motion of the pipes to another (water pipe and feet). This is contra productive to the idea of prefabrication and quick and easy installation at the school. Also, water would run through the connections into the post, which reduces the water quality and would also affect the concrete footing. The connection of the pipe to the feet with a union connection seems to be the most adequate solution for a fast installation at the school after the prefabrication process. However, the quality of the union connection must be high.

The most important finding of the assessment regarding the used materials is the sustainability of the **individual faucets**. In the beginning, added to promote iHWWS with the Core Module, the assessment clarified that after around two months14% of the faucets were already broken or apart. The whole system cannot work anymore, if the faucet is apart, due to the big hole in the water pipe system and the lost hydrostatic pressure. Also, if the functionality is given again after repair, the reputation of the facility falls, which leads to less ownership and care. The main selling point of the facility is the sustainability and durability of materials and usage. The use of a faucet – regardless of whether it is brass or plastic - undermines the sustainability and poses a threat to the recognition of the Core Module.

This leads to the conclusion to exclude an individual faucet in the next design. But still, the Core Module should give an option for individual hand washing with a reduced amount of water usage.

Water Management

The discussion of water management aspect is, like in the sections before, divided into the parts Enhancements and Refilling Process.

Structural Enhancements

Research in Cambodia showed that 91.7% of the principals want to improve their hand washing activities, but they only have funding of around 60$ per school year for WASH activities (Shantz, 2013, p. 17). This demonstrates the limited financial resources of the school community on the one hand, and the willingness for improvements on the other. It is essential for technology in schools to leave space for community participation to raise ownership, since participation and collaboration is crucial for the sustainability in school WASH (Cantwell, 2014, p. 4). The Core Module encourages communities to upgrade it. Upgrades or enhancements can be done in various ways with only little efforts. 'Enhancements' were defined as any kind of additional work, added to the facility with a positive effect. A simple enhancement is the construction of a rack to elevate the water bucket, a more advanced one is the connection to water pipe or the setup of a basin.

The results shows the ability of a school community (even in extreme situations like after a typhoon) to enhance the facility, based on school needs and conditions. After all, 70% of the facilities were improved by the school community. Interestingly 4 schools enhanced some but not all facilities installed at the school, which may be because of limited resources for all Core Modules or due to different responsibilities within the school for the facility.

It is important to understand what leads school communities to enhance their facilities. The 'Enhancement Ratio' demonstrates how many of the installed facilities at a school ground are enhanced. Since the number of Core Modules at a school varies a lot from 1 up to 9, and the number of schools are also different (1 school with 9 facilitates, 19 schools with 2 facilities) the ER gives an insight, but is not a statistical valid instrument.

Taking a look at the **number of facilities** installed at one school, there seems to be no big difference in the ER. It seems to be reasonable that a small school with only one facility can enhance it with less effort than a big school with many facilities, but also the resources of a big school are greater. This also proves that a large number group wash facilities can be managed by a school community.

In 35 schools the principals were female, in 14 they were male. There is a higher chance in the schools under **male leadership** for enhancements. One reason could be that the student population in male schools is on average higher than in female schools (539 to 343), an indicator that these schools are more in urban areas with better infrastructure, than in the countryside.

Taking a look into the **municipalities** where the schools are located, there is a link between the number of schools and the possibility for enhancements. The average ER in municipalities with 3 schools is 0.82. The highest value is 0.90 in one municipality with 11 schools. The differences are explainable in several ways. First of all, some areas in the north (e.g. Batad) were more affected by the typhoon than those who were in the south or further away from the coast (San Rafael). Resources like labor, time and money were needed at many places at the same time in highly affected areas, often also private houses were totally destroyed. Secondly, there can be distinctions in the political level about the priority of tasks. It is clear that future installations in schools need to be accompanied by supportive governmental structures to advocate the idea of group wash activates in schools.

The contentment with the facility is high. 48 schools are pleased with the Core Module, only one 1 school is not. However, the feedback from this school is also positive, the student feedback is ‘happy’ and they like that it is possible to wash hands in a group. The ER was 1.00 (all facilities were enhanced) for the two schools which are particularly content, as well as for the not-satisfied school. This also shows that if there are doubts or discontentment within a school, the community is willing and able to enhance the Core Module. The majority of the schools (46) said that they are content with the facility, but not all of the Core Modules had enhancements at the time of the assessment. Obviously, the contentment itself is not the only dominant factor to promote enhancements.

After the installation, staff members of Fit for School Inc., a national non-governmental organization, went to the schools to conduct **orientation workshops about EHCP** Approach. Summarized, the goal of the workshops is to equip the school leaders with the skills and knowledge they need to implement daily tooth brushing and hand washing activities. Also, the beneficial effects of supervised group activities (less time, assuring cleaning, fun activity for kids) were taught in this workshop.

Due to this motivation aspect and the understanding of the reasons why Group WASH activities can have a positive effects in the school community, there is a higher chance for enhancements. The average ER for schools without an orientation workshop is only 0.53, compared to 0.76 who know the advantages of group wash activities. For further installation, it is important to ensure orientation workshops either before or directly after the installation at the school ground.

Refilling Process

Another aspect covered by the assessment was the refilling process of the bucket. Since water availability with a main pipe system at primary schools is often a great challenge, the Core Module works with a self-contained bucket. The idea is that the bucket gets refilled manually. Several aspects are important for this process to be implemented on a regular basis. The following part of the thesis highlights this process and points out problems and solutions.

The five gallon tank is connected to the Core Module with a flexible garden hose. To ensure the required hydrostatic pressure, the bucket needs to be elevated. Only 10% of the Core Modules were attached to a pipe system. Schools created several solutions for the elevation, but 23% of all buckets were not elevated at the day of the assessment. These buckets were elevated by somebody, which is a possible scenario for the group wash activities, but also prevents individual hand washing outside the group activities. The most of the Core Modules have a rack (35%) with an average altitude of 164cm and filling level of 36%. This is the lowest level of all solutions and also the highest (average) altitude. The highest filling level (62%) goes along with the smallest altitude (159cm) for the solution of attaching the bucket to a roof or building.

It is reasonable that it is more comfortable to refill a bucket that is not so high, especially seeing the point that in all 43 schools where the Core Module works without piped water, the **students are responsible for the refilling process**. In some schools they get assistance by adults like the teachers or guards.

The implication for the findings are clear. The way the bucket is elevated is not child friendly at the moment. The bucket is simply too high to be refilled by students easily.

The conclusion is that the bucket will be not refilled frequently to ensure group wash activities and individual hand washing.

Interestingly, the refilling process is organized in **small student-teams**. In general the participation of student groups is desirable to promote social skills and create a culture of responsibility within the students. Of course, it is important that the tasks are organized in a fair and transparent way and to prevent that these tasks are part of punishment for bad behavior or grades.

Other research had shown a connection between the **distance to a water source** and the frequency of usage. Typically, the quantities of collected water decrease significantly, if the time to take the water exceeds around 5 minutes or the water source is more than 100 meters from the house (Howard & Bartram, 2003, p. 18). In this study 67% of all facilities had a water source within 1 up to 20 meters distance, but there is no evidence for a higher filling level if the source is near. Before the installation, in many schools there was a trade-off as to where to install the Core Module at the school ground. Ideally the facility should be near the classrooms and toilets, to make group activities easy and also promote individual hand washing after using the toilet. But often the toilets where further away. Also, a location near the cafeteria, or a shady place where the students often have lunch, would be a good place for the group wash facility.

The place of the facility is also connected to the **time they need to refill the bucket**. 67% percent of all school need less than 5 minutes for the refilling process, which seems to be a practical time to ensure daily refilling.

For domestic usage, there is a relationship between the time it takes to collect the water and the amount collected. If it takes more than 5 minutes, the water consumption will drop dramatically from 50 liters to nearly 15 liters (see Figure 28). A location near the water source reduces the need to transport the water to the Core Module and can promote the usability.

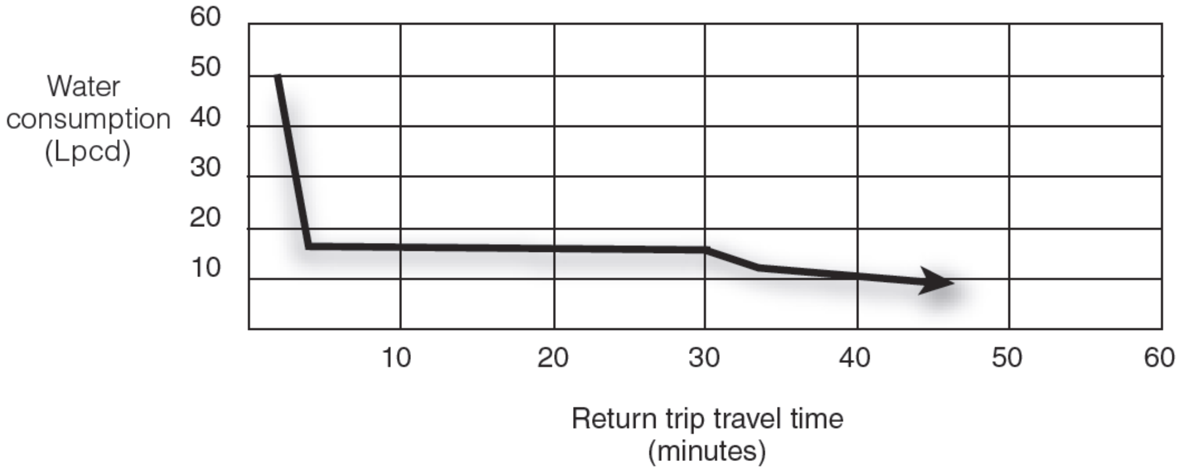


Figure 29: Relationship between water collection journey time and consumption (WHO, 2011, p. 3)

However, the time needed is also determined by the way the school organizes the refilling process and the materials used.

The main complaint of the schools is the bucket. In detail they mentioned the size of the bucket, the difficult refilling process and the elevation. Especially the narrow opening of the used water tank, which complicates the refilling. These complaints are in line with the findings above and prove the necessity for a new solution, which will be discussed later. In addition, the durability of the individual faucet and the location at the school yard raised complaints. But overall the feedback of students, parents and teachers is positive. Most of the stakeholders are seeing the positive emotional and practical effects of the Core Module, which is not always given. In Cambodia for example, 83% of the school directors are not satisfied with their hand washing facilities (Shantz, 2013, p. 15)

The full potential of the Core Module can be utilized if it is used from both sides. 27% of all facilities were installed in a way to make it impossible to use it from both sides, which demonstrates clearly an insufficient and incomplete introduction of the Core Module at the school. Another promoting effect in the schools is a protective roof over the wash area, to protect students from rain and sun. However, only 7% of the Core Modules had a roof.

Initially it was planned to install the facility with **a height for the water pipe of 110cm**. The average height in reality is 132cm, which is too high for enjoyable wash activities for students, because of water splashes. The reason for the higher altitude can be the solid ground, which makes it harder to dig deep enough holes. In addition, the height of the bucket needs to be higher if the water pipe is high, which increases the problems of the refilling process. Easy accessibility is crucial for the daily usage of WASH facilities (Shantz, 2013, p. 4)

For future implementations it is crucial to explain all functions of the Core Module clearly to the school stakeholders. This includes the possibility to access it from both sides, as well as the minimization of water usage. As this study proved, only a little amount of water is enough to wash hands properly, this knowledge had to be shared with the school community.

Limitations: Technical Assessment

As mentioned earlier, a limitation of the study is the post catastrophe scenario at the schools. Many school community members were personally affected by the typhoon Haiyan, teachers as well as parents and students. In addition, the infrastructure was partly destroyed, electricity was often not available and building materials were primarily used for reconstructions. Although the research was able to point out important facts to improve the Core Module for the future. Required modifications will be demonstrated in the next chapter.

Conclusion

The microbiological trial proved the effectiveness and efficiency of the Core Module. The technical assessment delivered several important facts, which are important for a modification of the design of the Core Module. The manufacturing process of the facility was well done and no structural mistakes occurred, also the idea of a pre-assembling at a workshop and the final installation at the school ground was working out well. The union connections are an easy solution to connect the Core Module in a short time, with little efforts and not many tools. But recapitulating the following technical challenges and problems were mentioned in interviews and are obvious based on the collected data set:

1. Elevation of the bucket: Schools had difficulties to elevate the bucket properly. Many buckets were too high to make a refilling by students easy.
2. Design of the bucket: The narrow opening of bucket makes a refilling difficult.
3. Garden hose: The flexible garden is not always connected well to the facility, also the durability of the garden hose is not given.
4. Altitude of the water pipe: The facility was not installed at the targeted 110cm.
5. Individual faucet: The durability of the individual faucet is questionable. As well the water consumption is higher.

This points are the identified problems. Based on these learning the EDP loop can start again.

After taking all mentioned problems in consideration, researching the need and developing several solutions for the problems, a new design for the facility was created to face this challenges. The new design shown in figure 27 on the next page.

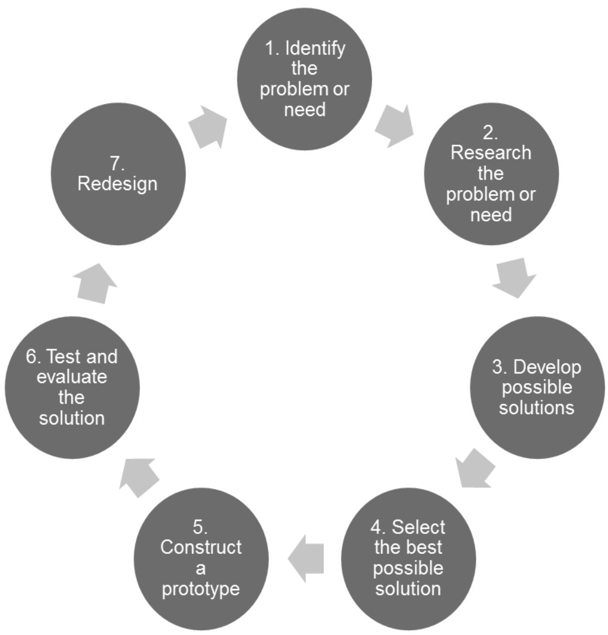


Figure 30: EDP Loop

The Core Module – Redesign 2014

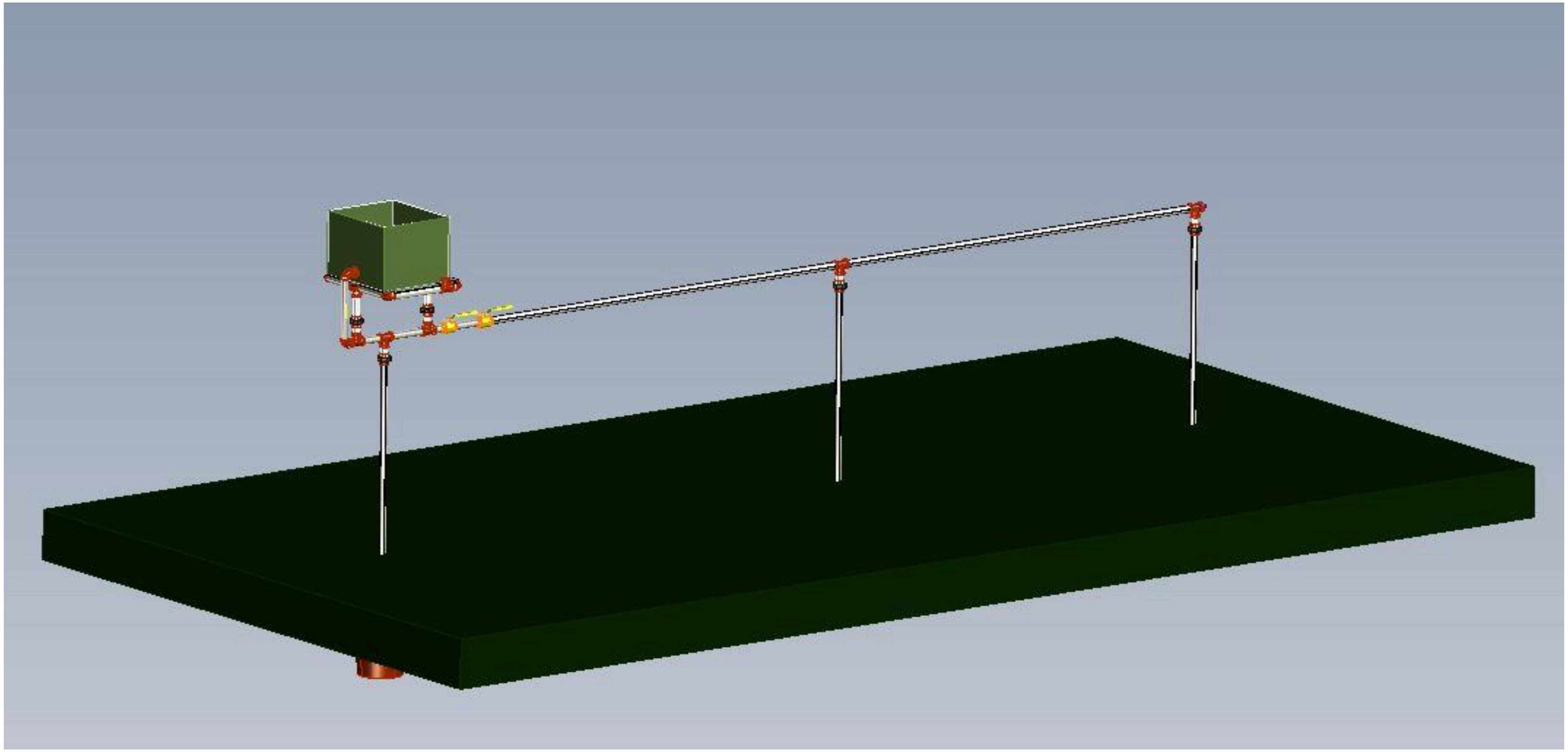


Figure 31: Redesign for next generation of Core Modules

The water supply is totally reviewed in the new design. To make refilling and also cleaning easier for the school communities, the new bucket has a wider opening. To take away the great challenge of elevation the bucket is now placed on a bucket holder system, also formed by widely available plumbing parts. The holder is attached to the water pipe over a union connection, like the posts also. The bucket holder can be also prefabricated, for transportation the 'feet' of the bucket holder can be folded.

Since in the assessed design, the coupling between the GI plumbing parts and garden hose could cause leaks and the flexibility of the garden hose goes in line with lesser stability, the supply from the bucket to the pipe system itself is now manufactured with a GI plumping parts (bulkhead, elbow, double nipple).

On the water pipe, the major change is the use of two valves instead of one. The first valve can be opened for individual hand washing, since a borehole is in the double nipple between the both valves. The borehole saves water compared to an individual faucet (see Results). If the second valve gets opened the water runs through the whole pipe system, where 22 students can wash their hands at 11 bore holes at the same time.

The length of the posts are shorter, due to the observations of high facilities.

Significance of results

Personal hygiene is a major topic in all developing countries. Simple and low cost activities like hand washing or tooth brushing promote healthy life conditions and makes a positive change possible. Still in many countries worldwide the priority of water, sanitation and hygiene promotion is not high. Often investments for interventions are high and require maintenance follow up activities with skilled workers. This is why an upscaling of ideas, especially if hardware is needed, is often difficult. The idea of the Core Module is to make this upscaling possible with a reasonable price and systematic for installations also in rural areas with insufficient infrastructure. To ensure daily hygiene activities in schools, it is important that the technique works reliably. This study helps to make the next big step towards a sustainable solution for group hygiene activities in schools.

Further Research

Further research activities in this sector should concentrate on two aspects: The durability of the hardware and the sustainability of the implementation.

This study is not a long time observation, however it is interesting to understand what condition the materials will be in, after exposed for several months or years in the sun, rain and salt water in coastal areas. Surely, the lifetime of the Core Module can be extended if school community maintain it. Investigations in maintenance activities of school communities regarding WASH facilities are in general a topic of rising interest for many stakeholders. What skills, tools and resources are necessary to ensure a long-life performance of products and installations? How can these activities be implemented in a day to day school routine? Or can maintenance and cleaning tasks for students even be a part of life-long learning approach?

Clearly observations in schools are necessary in the future to spotlight the implementation process. A common practice for WinS programs is to transfer the responsibility for the implementation of approaches to the principal of the school. Maybe other ‘change makers’ are needed within the school community, since principals are often overwhelmed. Research is needed to understand what these change makers need, in tools or skills, to fulfill their tasks.

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Erklärung

Hiermit erkläre ich, dass ich die vorliegende Arbeit selbständig und eigenhändig sowie ohne fremde Hilfe und ausschließlich unter Verwendung der aufgeführten Quellen und Hilfsmittel angefertigt habe.

Marcel Siewert, Januar 2015