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Towards Practice-Oriented Higher Education for Sustainable Rural Development in Western Kenya

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List of Abbreviations

BBB	Big Blue Button
BUAS	Brandenburg University of Applied Sciences
CBO	Community Based Organization
DAAD	Deutscher Akademischer Austauschdienst
DICOMSE	Digitalization and Collaboration in Mathematics & Science Education
EADPS	East African Organic Producers Standards
FTP	File Transfer Protocol
FDM	Fused Deposition Modeling
GDP	Gross Domestic Product
HNEE	Hochschule für nachhaltige Entwicklung
ICS	Internal Control System
KACRWASCO	Kakamega County Rural Water and Sanitation Company
KACUWASCO	Kakamega County Urban Water and Sanitation Corporation
KES	Kenyan Shilling
KIRDI	Kenya Industrial Research and Development Institute
KNBS	Kenya National Bureau of Statistics
KOAN	Kenya Organic Agriculture Network
KOFA	Kenya Organic Farmer Association
KOPA	Kenya Organic Producers Association
MMUST	Masinde Muliro University of Science and Technology
ProUniEdu-WeK	Practice-orientated University Education in Western Kenya
SAVET	School of Agriculture, Veterinary Sciences and Technology
SEDU	School of Education
SDG	Sustainable Development Goal
SDI	Slum Dwellers International

SME	Science and Mathematics Education
SONAS	School of Natural Sciences
SPHBST	School of Public Health Biomedical Sciences and Technology
THB	Technische Hochschule Brandenburg
UNICEF	United Nations International Children's Emergency Fund
WHO	World Health Organization

Practice-oriented University Education in Western Kenya – Goals, Results and the Way Forward

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At the end of this once again difficult year 2021, we look back on a successful cooperation between the Brandenburg University of Applied Sciences (THB) and the Masinde Muliro University of Science and Technology (MMUST) in Western Kenya, which began in 2017 and has now been funded by the DAAD for almost 4 years.

This volume contains the written versions of the presentations given by the Kenyan participants of the final workshop, which took place in August 2021 at the Technische Hochschule in Brandenburg an der Havel. The contributions give an impression of what has been achieved in recent years on the way to a more practice-oriented higher education in the participating departments of MMUST and what is still to be done in the near future.

The cooperation between THB and MMUST started with a project between THB and the NGO Agrokenya, which was founded by THB's Kenyan alumnus Suleiman Kweyu after he graduated in 2017. Shortly after its establishment, MMUST became involved through a tripartite agreement between MMUST, THB and Agrokenya. As a support to local farmers in the Kakamega region, the first "materialised" aid was the installation of a flow-driven water pump invented by the Magdeburg-Stendal University of Applied Sciences (HMS) in the Lusumu River. A few months later, THB received a two-year DAAD grant with the aim of contributing to a German-Kenyan network that would lead to a German-Kenyan university of applied sciences.

Now, in addition to the School of Agriculture, Veterinary Sciences and Technology (SAVET), other faculties and departments of MMUST and THB have been included in the DAAD-funded project "Practice-oriented Higher Education in Western Kenya" (ProUniEdu-WeK). In addition, to cover the important areas of agriculture and engineering, two other German universities of applied sciences - the Eberswalde University of Applied Sciences (HNEE) and the above-mentioned HMS - were involved through formal agreements and real professors.

In this composition, teachers and researchers have now been working successfully for 4 years in international and multidisciplinary teams on practice-oriented concepts for university teaching. Originally, the project was to run only until the end of 2019 as part of a DAAD-funded network, but - in the expectation of further results - it was extended until the end of 2020, without, however, having in mind the consequences of the COVID 19 pandemic, which were not yet foreseeable at that time. These meant, among other things, that neither the planned trips nor live workshops could take place in 2020.

Thanks to an agreement with the DAAD, it became possible to transfer funds earmarked for these measures into funding for equipment and software to support practice-oriented and online teaching via a sub-award agreement. In addition, a further extension of the project until the end of 2021 was made possible by the DAAD, so that we can now look back on more than four years of cooperation between researchers, lecturers and professors from the institutions mentioned above.

Despite the continuation of the pandemic in 2021, it was not only possible to hold a joint final project workshop at BUAS in August 2021, but also several more trips by German professors to our Kenyan partners to take part in the STEMEIC conference as well as final workshops of the sub-projects in the fields of agriculture, energy and chemistry, medicine and computer science and to prepare the continuation of these projects in the coming years. An important task here was the follow-up to the above-mentioned workshop in the form of the preparation of this publication, in which the ideas and results of the ProUniEdu-WeK project are to be made known to a wider public.

The structure of the conference proceedings presented here corresponds to the architecture of the ProUniEdu-WeK project, which results in a canonical manner from its goals and components:

A stronger practical orientation of the education at MMUST means producing graduates who, especially in the traditionally agricultural area of Western Kenya, can be immediately effective in the economy after their education. According to the experience of German universities of applied sciences, this can be achieved particularly well by working on practice-relevant tasks during the course of study.

This includes internships, practice-oriented courses, projects and, in particular, cooperation with the regional companies in which the graduates will later be employed. The present region of Western Kenya with the regional centre of Kakamega is mainly characterised by its rural character and agriculture. From this follows the central importance of agriculture and rural regions as the main field of employment for graduates and as the main field of application of applied research and in this publication accordingly the first block *Agriculture and Rural Development* with the first three contributions. All following papers belong to contributing sciences with the aspect of multidisciplinary contributing sciences.

At this place I wish to thank especially all Kenyan authors for their contributions, but also my colleagues from BUAS, HNEE and HMS for their support in finalizing these proceedings.

I would particularly like to thank Swana Gerriets, a Master's student of BUAS, who has given me excellent support with corrections and formatting in the last few days and under great pressure of limited time. I accept responsibility for any errors still present.

Agro-Intensive Crops and Livestock Production for Food Security and Biofuel Utilization in Kakamega County, Kenya

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Abstract

Close to half of the Kenyan population are food insecure, and a large proportion of children under five exhibit micronutrient deficiencies. Currently, over 10 million people in Kenya suffer from chronic food insecurity and poor nutrition, and between two and four million people require emergency food assistance at any time. Food insecurity, malnutrition, climate change, rural poverty, unemployment, and environmental degradation, especially in sub-Saharan Africa, have become matters of grave concern and discussion. This project aimed to develop and use digital means to assess the effects of agri-intensification of crops and livestock production and its availability, nutrition, and food security in western Kenya. The study started with acquiring a bio-digester for Masinde Muliro University of Science and Technology and the collaborating farmers of Agrokenya from Mumias East. This was followed by a sociological survey among small-scale farmers in three sub-counties, Malava, Mumias East, and Lurambi, to assess their food situation and their perception of using the bio-digester at the household level to improve their food availability and utilization of gas. A sample size of 100 small-scale farmers was interviewed at the household level. This was followed by installing the two bio-digesters for demonstration purposes for gas production and bio-slurry for crop production improvement.

The result from a sociological study showed that sixty percent (60%) of the sampled farmers were females, with only 40% as males. However, it was clear that decision-making in this community is male-dominated. It was also established that thirty-three percent (33%) of small-scale farmers use a mixture of both organic and inorganic fertilizers. Eleven percent (11%) use organic fertilizers alone, and fifty-six percent (56%) use inorganic fertilizers for their crops despite getting inadequate yields. The knowledge acquisition process gives a farmer the necessary understanding for decision-making. Education levels of the farmers were low, with the majority thirty-eight (38.8%) having only a primary level of education. A good education will assist farmers in decision-making. This was highly linked with the inorganic fertilizers' availability and high cost compared to organic fertilizer. Therefore, it is hoped that the introduction of bio-digester will encourage farmers to use more organic fertilizer. The study was carried out in Kakamega County of western Kenya with the support of Masinde Muliro University of Science and Technology (MMUST), Brandenburg University of Applied Sciences (BUAS), and Agro-Kenya, an NGO that supports the community particularly during this period of the COVID-19 pandemic.

Keywords: Food Security, Biogas, Bio-slurry, Biodigester

Introduction

The dramatic global food security recorded in the last three decades has increased the number of poor people in the Sub-Saharan and South Asian regions (SCN, 2010). Kenya is among countries that have the highest number of food-insecure people who survive on less than a dollar a day (Wambogo et al., 2018). An estimated 36.5% of the country's population is food insecure, and 46% live below the poverty line (Boateng *et al.*, 2020). According to the Global Hunger Index (Index GHI, 2019), over 35% of the Kenyan population suffer malnutrition and food insecurity annually, with an approximation of 2,6 million people likely to be negatively impacted by the food insecurity crisis.

About 80% of Kenya's population live in rural areas and depend directly or indirectly on agriculture for their livelihoods (FEWS NET, 2010). Only 12% of Kenya is considered the high potential for farming and intensive livestock production. A further 5.5%, classified as medium potential, mainly supports livestock, primarily sheep and goats. Only 60% of this high and medium potential land is devoted to crops (maize, coffee, tea, horticultural crops, etc.). The rest is used for grazing and forests (NIB, 2003). High potential zones are located in the highlands, where temperatures are pretty low (FEWS NET, 2010).

Efforts to produce enough food for Kenyans have never achieved intended outcomes because of declining soil fertility, increasing population, shrinking arable land due to urbanization (Waithaka et al., 2007). Human activities, for instance, over-harvesting of trees and vegetative cover as the primary source of fuel, have led to the experienced climate change, which has adversely affected crops (Kogo et al., 2021). A reversal of the above limitation cannot be achieved unless radical and innovative new systems of crop production, as well as eco-friendly sources of energy, are introduced and widely adopted by farmers (Yadav et al., 2017). Such systems should sustainably increase agricultural productivity on non-expanding land size without compromising the environment. One way to achieve results in this direction is to use bio-digesters that produce cooking gas (which can be used instead of firewood for cooking) and, at the same time, produce organic fertilizer that can be used locally to improve soil fertility. The adoption of crop intensification and bio-slurry technologies has positively affected productivity and income in other parts of the world while safeguarding the environment (Singh et al., 2020). Figure 1 illustrates the principle of work of a bio-digester.

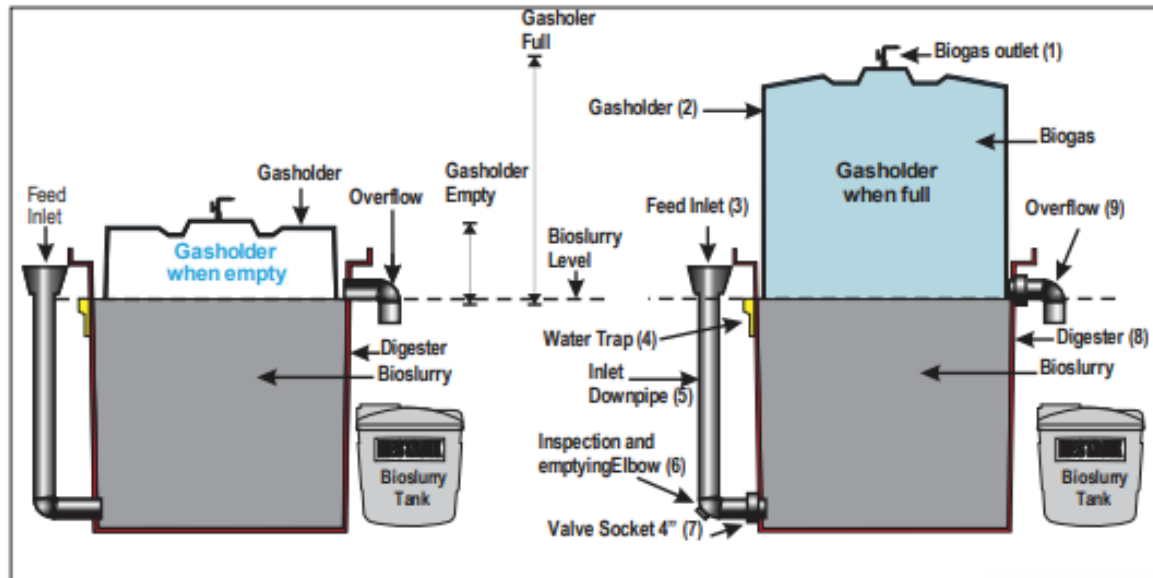


Figure 1: Bio-Digester Working Principle

The ongoing collaborative project ProUniEdu-WeK between Masinde Muliro University of Science and Technology (MMUST), AgroKenya, and Brandenburg University of Applied Science of Germany (BUAS), funded by DAAD (Deutscher Akademischer Austausch-Dienst), two bio-digesters produced in Kenya could be acquired for operation at MMUST and in a village close to Shianda.



Photo: (Alice Ndiema)



Photo: (Alice Ndiema)

The current project is intended to foster agro-livestock intensification in western Kenya to increase crop production, animal production as well as production of clean gas through the help of bio-digesters and, at the same time, find out practicability productivity enhancements.



Photo: (Suleiman Kweyu)



Photo: (Alice Ndiema)

To ensure the project's success, there was a need to survey the type of agricultural systems practiced by small-scale farmers in western Kenya and their awareness of biogas energy and production.

Research Methodology

The study employed a sociological inquiry technique to carry out baseline and identify crops and livestock systems in place in Kakamega County. This was conducted in Malava, Mumias East, and Lurambi Sub-Counties in Kakamega County, which was purposively selected based on the population size and crop and livestock farming activities carried out in those areas. A total of 100 households were randomly and purposively sampled for data collection. Interviews and questionnaires were used as the primary data collection tools among the sampled-out households in the three sub-counties. The key aspects covered by the questionnaire were: demographic information, educational background of the farmers, land sizes, farming system practiced, and awareness on biogas production and usage.

Results on the Sociological Study in Kakamega and Discussions

Gender as a Variable

The study results showed that most of the small-scale farmers in Malava, Mumias East, and Lurambi sub-counties are women (60%), while men are (40%), as shown in figure 2.

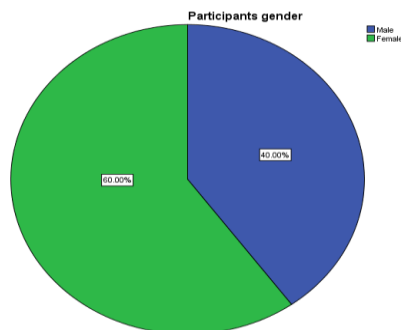


Figure 1: Gender Participation

Gender is a biological distinction between males and females among the respondent farmers, and it also refers to both biological and socially constructed differences between men and women Quisumbing, (1996). This study is measured as a categorical variable with male and female categories. Across regions, studies have shown that women work significantly more than men if caregiving is included in the calculations (Ilahi, 2000). The combination of commitments often means that women are more time-constrained than men (Blackden and Wodon, 2006). For example, women comprise fewer than 10% of the farmers involved in smallholder contract-farming schemes in Kenya. Only 1% of the sample 59 farmers contracted in Senegal to produce beans for the export sector were women (Maertens and Swinnen, 2009). In a sizeable contract-farming scheme involving thousands of farmers in China, women were excluded from signing contracts themselves to perform the bulk of the work related to contract farming (Eaton and Shepherd, 2001). Women may not be well compensated as unpaid family labour in contract farming schemes (Maertens and Swinnen, 2009).

Age as a Variable

The study further established that the highest percentage of these small-scale farmers are mainly composed of the middle-aged 36-45 (36%), followed by the elderly 46-55 (24%) and the senior elderly (above 55 years) at 18%. The teens and the youths aged 15-25 were ranked the least (7.1%) among the small-scale farmers in the county (Table 1).

Table 1: Small-scale Farmers by Age in Kakamega County

Participants Age					
	Age	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	15-25	6	7.1	7.1	7.1
	25-35	13	15.3	15.3	22.4
	36-45	31	36.5	36.5	58.8
	46-55	20	23.5	23.5	82.4
	>56	15	17.6	17.6	100.0
	Total	85	100.0	100.0	

Studies relating to farmer's age to his/her adoption behaviour reveal conflicting results, with some showing positive relationships while others reflect the strong negative relationship. Rogers (1995) argues that younger and more educated farmers are more inclined to adopt new practices. Adoption may vary as a function of a stage in the life cycle of a farmer and family.

Farmers Level of Education

Literacy plays an essential role in enabling farmers to access written material, thereby facilitating their awareness of information (Weir and Knight, 2004). Farmers whose ability to read and write is low tends to be disadvantaged in utilizing information.

Therefore, education increases managerial competence and enhances the ability to diagnose, assess, comprehend, and respond to financial and production problems (Molnar, 1985). It also enables them to choose wisely from a stock of available technologies and how to manage once the technology has been adopted efficiently. In addition, knowledgeable farmers assist researchers in guiding their focus.

Education Levels	Number	Percentage
Informal	7	8.3
Primary	33	38.8
Secondary	28	32.9
Tertiary	17	20.0
Total	85	100

Among farmers interviewed, 8.3% were illiterate, 38.8% had a primary level of education, 32.9% had secondary school education, with only 20% having attained tertiary education. There is a positive relationship between farmers' level of education and adoption behaviour (Chitere, 1985). This is consistent with other studies on maize (Misiko, 1976; Amudavi, 1993). Sing and Santiago (1997) found that the farmer's educational attainment influenced farm earnings in Mexico. In Africa, several studies have shown a positive relationship between farmer's education and farm productivity (DSE, 1992; Kahn, 1991; Knight and Shabot, 1990; Acker, D. G. (1988)).

Farm Size

The study results also showed that most of the small-scale farmers in Kakamega own small land sizes ranging from less than 0.05 acres to 1.1 acres of land. The majority of the farmers that account for 47% of the population owning lands ranging from 0.06-0.1 acres of land. Approximately 20% of the total population in Kakamega County own land that is not more than 1 acre (Table 2).

Table 2: Farmland Sizes for Small-scale Farmers in Kakamega County

Participants Farm Size					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-05	28	32.9	32.9	32.9
	0.06-0.1	40	47.1	47.1	80.0
	0.1-1	17	20.0	20.0	100.0
	Total	85	100.0	100.0	

The table below shows that most farmers (65%) practice mixed cropping systems, where they intercrop maize with legumes (beans and groundnuts), while approximately 35% of the sampled population plant maize only. (Table 3).

Table 3: Common Cropping systems in Kakamega County

Common Crops Grown				
	Frequency	Percent	Valid Percent	Cumulative Percent
Maize	30	35.3	35.3	35.3
Maize & Beans	33	38.8	38.8	74.1
Valid Maize & Groundnuts	22	25.9	25.9	100.0
Total	85	100.0	100.0	

Approximately 58% of the farmers practicing crop cultivation in Kakamega County also rear some dairy animals (Figure 3).

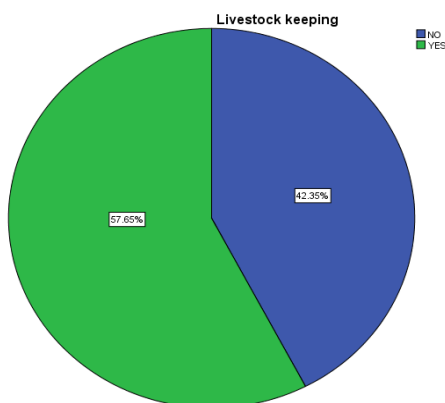


Figure 2: Livestock Keeping

The study also looked at the type of fertilizers used by small-scale farmers in Kakamega County. The results showed that the majority of the farmers (56%) use inorganic fertilizers for their crops. Thirty-three (33) percent use a mixture of organic and inorganic fertilizers, while 11% use organic fertilizers alone (Figure 4).

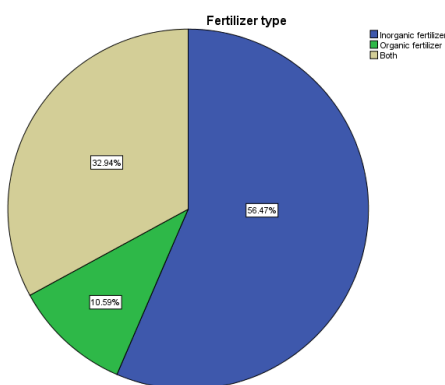


Figure 3: Types of Fertilizer Used by Small-scale Farmers

In terms of biogas production awareness, approximately 64% of the small-scale farmers in Kakamega County have heard about biogas production, while 36% have not heard about biogas production.

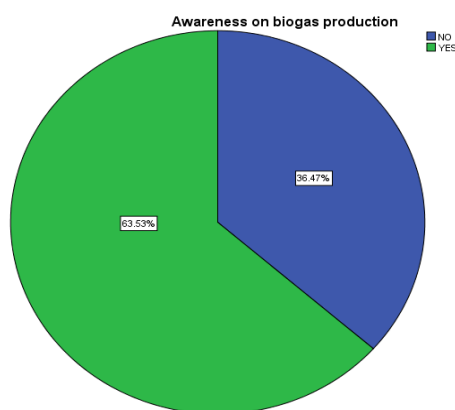


Figure 4: Biogas Production Awareness by the Farmer

Technology awareness is critical in allowing farmers to make informed decisions. During this survey, it was clear that 63.5% were aware of the bio-digester but did not have them on their farm. Therefore this calls for the promotion of this technology which has more benefit to the farmers. Once the farmer clears the waste from livestock, they can get clean gas for cooking and bio-slurry for crop production and soil improvement, which can be used for both food utilization and livestock feeds.

The current study will uncover the most suitable crops and livestock that can positively support food and nutrition security while increasing income generation among households in Kakamega County. As such, it is critical to determine the food and nutrition situation among the household members, particularly the women, to establish the status and most appropriate intervention at the household level that can address household food and nutrition insecurity. Therefore, the current study will examine the contribution of agricultural activities on livestock size, production, and income towards reducing the increased levels of malnutrition among children and how they can be empowered to address challenges facing them on the attainment of household food and nutrition security.

Conclusion of the Sociological Study

The study established that most small-scale farmers within Kakamega County are women aged between 36-45 years. Factors such as lack of enough farming lands, inadequate awareness and funds to purchase organic fertilizers, lack of diversification of crops, and rearing of livestock negatively impact food production in Kakamega County. There is also a lack of technological knowledge and unavailability of bio-digesters within reach of small-scale farmers. This will assist in effective and efficient utilization of the farm wastes from both livestock and other waste in the farm that can produce clean gas for cooking and bio-slurry for crop production.

Use of Clean Energy Biogas vis-à-vis Firewood

During this period, the bio-digester installed at Elwasambi village, Shianda of Mumias sub-county, helped demonstrate the different uses of bio-digester at the household level, including cooking and bio-slurry production for improving soil fertility. The family uses

the unit to produce biogas for cooking in quantities that can facilitate 2-3 hours of continuous cooking per day compared to the MMUST one of 2 hours. The amount of gas produced is sufficient for a half day's need.



Photo: (Vivian Namayi)



Photo: (Vivian Namayi)

Way forward

Development of an App for the Bio-digester

The **School of Computing and Informatics** was engaged to help develop an app that would aid students or any other users to measure, monitor, and control the bio-digester remotely. The app is intended to be installed in a mobile phone device, which would perform all the functionalities of **measurement, control, and monitoring**. The focus parameters are **temperature levels, gas**, and any other parameter of interest. The objective is to develop a system, which can send data through **FTP** and emails, perform reliable data storage, perform real-time calculations, and accurately perform the required measurements. It is hoped that when the development and integration are done, it will support home automation, control of heating/cooling systems, and environment monitoring, besides supporting students learning experience.

Chemistry Analysis of the Gas

Biogas plants are biological systems in which various microorganisms anaerobically degrade organic matter to produce biogas as the main product. The degradation process involves four successive biological processes: hydrolysis, acidogenesis, acetogenesis, and methanogenesis. If one of these processes is negatively affected, there is an instantaneous influence on the other processes and consequently on the amount and quality of biogas produced. Therefore, it is vital to characterize the biogas feedstock before being taken to the biogas plant for processing. The parameters to be tested will include pH, total solids, dry matter, volatile solids, organic dry matter, chemical oxygen demand, total nitrogen, and biochemical methane potential. In western Kenya, farmers keep different animals, and therefore different feedstocks are readily available for biogas production. From the feedstock characterization, the researchers will be able to choose the feedstock to be used.

Furthermore, during the anaerobic degradation process in the biogas plant, the effect of different parameters on biogas production will also be monitored. These will include pH, organic load, hydraulic load, and ammonia produced. This will help the researchers ensure optimal conditions for biogas production.

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Exploring Organic Farming Potential for Smallholder Farmers in Western Kenya

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Abstract

Organic farming is growing in importance worldwide due to environmental sustainability and health concerns. This is because of the general tendency to use natural production methods, thereby maintaining nutrient recycling, minimizing external input on the farm, and producing natural products with minimum external contaminants. It has many advantages: enhancing biodiversity, biological cycles, and activity. Organic agriculture directly contributes to several sustainable development goals (SDGs), including those for No. 1, 2, 3, 7, 8, 13, and 15. Organic farming is a growing sector worldwide, increasing under cultivation, production quantities, and consumption. In Europe, it is estimated that the area under organic agriculture increased by 49% between 2012 and 2019. In Kenya, though the area under organic agriculture is negligible, it is also considered growing fast. The main objectives of promoting organic agriculture in Kenya are to diversify food production at the household level in a sustainable way, promote ecological sustainability of the farming systems, and increase household incomes through market access. The sector is managed mainly by self-regulation, where producers are required to meet stringent production requirements for certification. Although organic agriculture in Kenya has primarily been practiced under medium to large-scale enterprises, smallholder farmers offer the most significant potential for its development. Many farmers predominantly practice farming with little or low external input, a critical factor in organic agriculture certification. Hence, it is believed that with minimum organization and training, accompanied by a sustainable market trigger, such smallholder farmers can achieve acceptable requirements for organic farming certification. This study is intended to explore the potential of smallholder farmers' aggregation, natural production environment, digital platform training, and market networks in promoting sustainable organic production using groundnut as a model low external input requiring crop in Western Kenya.

Keywords: Organic Agriculture, Organic Farming, Certification, Organic Products

Introduction

Organic Agriculture is a production system that sustains the health of soils, ecosystems, and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions rather than the use of inputs with adverse effects. According to the definition above, organic agriculture combines tradition, innovation, and science to benefit the shared environment and promote fair relationships and good quality of life for all involved and has four basic principles.

1. Health - sustain and enhance the health of soil, plant, animal, human, and planet as one and indivisible.
2. Ecology - based on living ecological systems and cycles, work with them, emulate them and help sustain them.
3. Fairness - build on relationships that ensure fairness concerning the common environment and life opportunities.
4. Care - managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

The importance of organic agriculture cannot be overstated. It supports the attainment of almost all the sustainable development goals (SDGs) and, more specifically, SDG no 1,2,3,6,8,12,13,14,15 (FAO, 2019). Organic agriculture also supports the achievement of food security, food sovereignty, and sustainable livelihoods. It is also at the core of the resilience and sustainability of food systems.

Status of Organic Agriculture

Globally, the land under organic agriculture has been steadily increasing over the last 20 years, from 11 million hectares in 1999 to 72 million hectares in 2019 (FiBL & IFOAM, 2021). The proportion of land under organic agriculture has followed a similar trend, rising from 0.3% in 1999 to 1.5% in 2019, translating into an average annual increase of 20%. Oceania makes up the most significant percentage of this land with 49.6% while Africa has the lowest at 2.8%. Oceania also has the highest share of organic agricultural land as a proportion of total agricultural land at 9.6%. In Africa, only 0.2% of total agricultural land is under organic agriculture.

Liechtenstein has the highest organic share of total agricultural land on a country basis at 41%. Austria and Germany follow it at 26% and 9.7%, respectively. In Africa, Egypt has the highest proportion at 3%. The shares for Kenya, Tanzania, and Uganda are 0.6%, 0.7%, and 1.6%, respectively. However, between 2018 and 2019, Africa had the highest growth of organic agricultural land at 9.5%, followed by North America and Europe. Africa's growth over the ten years between 2009 and 2019 was third highest after Oceania and Asia. These figures point to a high potential for the growth of organic agricultural land in Africa.

In terms of the global market of organic agriculture products, Africa is trailing all other regions with retail sales of only 17 million € compared to the leading regions of North America, Europe, and Asia that achieved retail market sales of 48,200 million €, 45,000 million €, and 11,000 million € respectively. This trend is also repeated concerning per

capita consumption, where North America leads with €132 followed by Europe at €56, while Africa lags with a negligible value of €0.01. This implies that most of the organic produce from Africa is exported. In Africa, Kenya ranks sixth in terms of organic agricultural land area with 154,000 hectares, while Tunisia leads the pack with 286,000 hectares (FiBL & IFOAM 2021).

History of Organic Agriculture in Kenya

Organic agriculture was introduced in Kenya in the early 1980s and has from the beginning been driven mainly by non-governmental organizations, faith-based organizations, individuals, and CBO's (Kamau et al., 2018; KOAN, 2018). The primary objective of these organizations was environmental conservation, poverty alleviation, and food security for rural smallholder farmers. A few private horticultural companies were involved in production for export, especially organic vegetables. In the early 1990s, organic farmers' organizations were founded, e.g., Kenya Organic Farmers' Association (KOPA) and Kenya Organic Farmers Association (KOFA). Initial attempts to have an organized local and export market were made in the early 2000s. The Kenya Organic Agriculture Network was established in 2004. The first-ever intervention of government agencies was recorded in their participation in developing the first-ever East African Organic Producers Standards (EAOPS) and the draft organic agriculture policy (Leregger and Omollo, 2014).

As a result of this objective, organic agriculture has, until recently, been viewed as an intervention for rural low-income farmers against poverty, food insecurity, and environmental degradation. This perception has had a significant negative effect on the growth of organic agriculture. There has been little or no syllabus for organic agriculture informal education, and it has not been part of the messages of the government agricultural extension services.

Problem Statement

Kenya is a low-income country where over 36% of the population lives below the national poverty line, while 50% are categorized as poor in the multidimensional poverty measure (World Bank, 2020). Agriculture is the mainstay of Kenya's economy, provides livelihoods for over 80% of the population. It accounts for 65% of Kenya's export earnings and employs over 40% of the population. Agriculture contributes 25% of GDP in Kenya, where over 70% of the population lives in rural areas. Currently, 36.5% of Kenyans are food insecure, and 35% of children under five are chronically malnourished. Western Kenya counties have some of the highest poverty levels and have the highest incidences of food insecurity. In 2014, Kakamega County was ranked the highest contributor to national poverty because of its high population (KNBS, 2017). In 2016, Busia County had the highest food insecure population in western Kenya, ranging between 20-25%.

Farming in western Kenya is mainly rainfed, with only a few farmers engaging in small-scale irrigation of vegetables along river banks during dry seasons. This kind of agriculture is highly vulnerable to climatic variations, with farmers becoming increasingly vulnerable to drought and the unpredictability of weather patterns resulting

from climate change. With a high population increase, there is raised competition for natural resources, primarily agricultural land, which is overexploited, leading to environmental degradation.

Organic agriculture would be a viable solution to the challenges facing smallholder farmers in western Kenya since it has been demonstrated to achieve sustainable ecological systems. However, organic agriculture is generally very poorly developed, especially in rural areas. There is limited knowledge of organic agriculture, and the inefficient agricultural extension services deteriorate the situation following the devolution of agricultural services from the national government to county governments. Worse still, there is generally limited coverage of organic agriculture by the formal agricultural extension and education systems.

Despite these many challenges facing farmers in rural areas of western Kenya, organic agriculture has the potential to enhance the region's livelihoods because of several advantages that this region has. Firstly, vast areas can easily convert to organic agriculture since they have had little or no use of external inputs that are detrimental to organic agriculture, such as chemical fertilizers and agrochemicals. Secondly, the region still has large parcels of unused land, making rotation and separation of organic from inorganic agriculture possible. The farmers in this region generally face financial challenges in purchasing external farm inputs. Hence organic production would be more appealing to them. Consequently, a systematic approach to developing organic farming would be very beneficial in enhancing the livelihoods of the communities in this region.

Project Objectives

The project's overall goal is to enhance the livelihoods of smallholder farmers in western Kenya through the exploration of organic agricultural product value chains. Specifically, the project will strive to engage in the market-oriented production of organic products. The project will enhance training on organic agriculture in the entire agricultural production system, including formal education, agricultural extension, and farmers. It will also endeavour to enhance access to the traditional agricultural markets locally and internationally by facilitating certification of smallholder farmers' systems for organic production.

Project Approach

The figure below shows a schematic presentation of the project concept to enhance livelihoods through the organic products value chain approach.

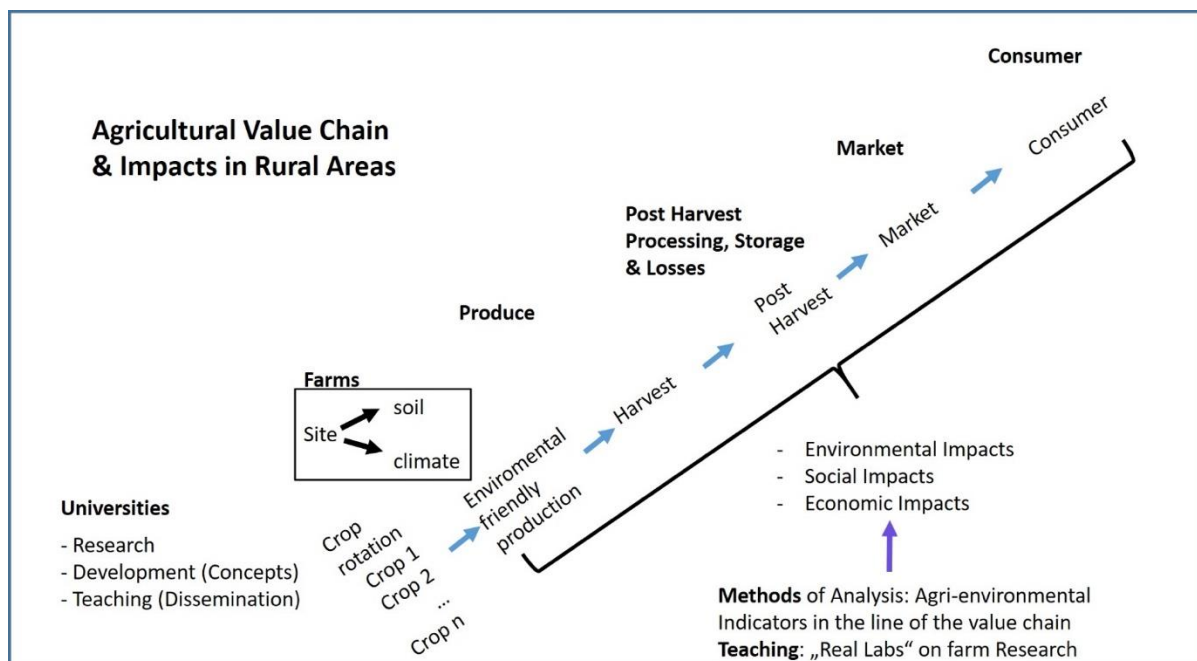


Figure 1: Schematic Presentation of Organic Agriculture Project Concept (Piorr 2021)

The project targets organic farming through agricultural product value chain production. The initial target crop is groundnut (peanut). The justification for the selection of groundnut is

1. a hardy crop with little or no external input requirements. Most farmers in the target region grow groundnut without applying any inorganic fertilizer, not spraying any chemicals for disease and pest management. They prefer to use the external inputs on other commercial crops like maize.
2. highly adapted to the local growth condition of western Kenya. The crop grows optimally under the soils, rainfall, and temperature regimes.
3. preferred because it is a non-perishable crop. This implies that the producers can store it for a long time, especially when low market demand. Farmers can also explore distant markets without needing additional specialized equipment for storage.
4. a highly valuable climate-smart crop. It is a legume with nitrogen-fixing capability, meaning it has low demand for artificially produced nitrogenous fertilizers. Furthermore, it is a cover crop that is very effective in soil erosion control and conservation agriculture systems. Also, it is tolerant of most pests and diseases, leading to minimal use of external inputs.
5. a high gross margin crop on the local market compared to other crops grown in this region than the most widely cultivated crops such as maize and beans. It can hence be easily to the local market as ordinary produce during the period of conversion of smallholder farms from conventional to organic farming.

The project will pursue market-oriented production for organic products. Firstly, the market will be identified, and the market will be analysed. Secondly, the market and the customer requirements are determined and applied in production. For organically produced groundnut, the market is major foreign, with most exported products. Local

retail sales and per capita consumption are negligible, as discussed above. The model adopted by the project is that of reaching export consumers through established importers and retailers. Hence the project will endeavor to establish networks with established organizations in Germany that trade in organic groundnuts. Here, the objective will be to establish, through German traders and farmers' cooperatives, the consumer demands, import requirements and standards, and quantities as illustrated below.

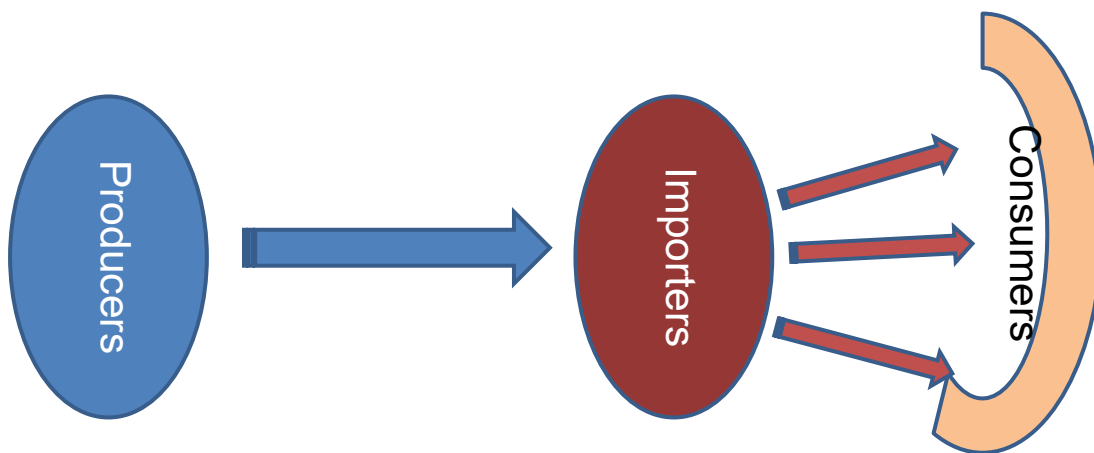


Figure 2: Linking Organic Producers with Consumers through Importers (Ogemah 2021)

Curriculum Development and Training

Armed with the above requirements, the project team will embark on a training program to help the farmers achieve the required standards. The first category of trainees is university students who are deployed to agricultural extension services mainly after graduation. There will be a need to review the curriculum that leads to first-degree holders and diploma and certificate students. The curricula will be enriched with organic agriculture content in theory and practice and then approved through the existing program approval and accreditation processes. Once the curricula are approved, there will be a need to prepare the training ground by ensuring adequate infrastructure for training, including practice-oriented teaching and practical lessons. A demonstration farm for organic farming shall be established at Masinde Muliro University of Science and Technology to train students, extension workers, and farmers.

The project will also develop a curriculum for farmers' training. The farmers will be trained in organic agriculture in general but specifically in producing organic products for the export market. Key components of the training will be production, certification requirements, value addition, and virtual learning. The project will endeavor to develop adequate practice-oriented training where the students will learn alongside practicing farmers on their farms as well as support the training of farmers as part of the student training.

Farmers' Aggregation and Certification

At the farm level, the project will pursue a farmer aggregation approach to work with farmers in groups. The project will initially target a group of 40 farmers as an excellent working average. However, it will adjust in terms of the number and size of groups in line with the market demand for organic products. The project will work out a program to support the certification of farmers for organic production. This will follow the group certification system with Internal Control System (ICS) (Ndiritu, 2016). In group certification, a group of farmers implement an Internal Control System (ICS) and are certified collectively by a third-party certification body, which assesses the performance of this system. Group members operate under contractual or binding membership requirements specifying the commitment to comply with applicable organic standards and permit inspection. Through the ICS mechanism, the group decides on members' compliance with applicable standards.

Organic Agriculture Research

Although there is sufficient information to support organic agriculture, most of it is not location-specific. For successful implementation of the project and enhancement of productivity, local information will be gathered and analysed in project-specific research that will focus mostly on agri-environment indicators. Masinde Muliro University of Science and Technology will play a central role in leading local research both on-station and on-farm. A participatory research approach will ensure that the information generated is relevant and applicable to the farmers involved in the project. In line with this research, the component will be developing and testing agri-apps for use in virtual training of farmers, data collection, and provision of agricultural extension services.

Production for Local and Export Market

The project's ultimate goal is to produce organic products for the export market. However, as discussed above, initial production will be for the local market during the process of conversion from conventional to organic farms. Therefore, the project will have to support extensive market research both for local and export markets. The consumer preferences and consumption levels will be established in establishing contract farming between the farmers and a network of markets, buyers, and consumers.

	TIME FRAME (MONTHS)												
ACTIVITY	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27	28-30	31-33	33-36	37++
Establish the status of organic farming in Kenya													
Establish Model organic farm in Kenya													
Development of curriculum for students and farmers													
Development of agro apps for training													
Identify the market for organic groundnuts													
Identify certification requirements													
Development of an app for training													
Training farmers for certification													
Training farmers on value addition													
Application for certification													
Production for local market during the conversion period													
Production for the export market													

Table 1:
Proposed
Project Work
Plan

Table 2: Growth of the Organic Agricultural Land and the Organic Share 1999-2019 (Source: FiBL-IFOAM-SOEL Surveys 2001-2021)



Table 3: Organic Agricultural Land (including in-conversion areas) and Regions' Shares of the Global Organic Agricultural Land 2019

Region	Organic agricultural land [hectares]	Regions' shares of the global organic agricultural land
Africa	2'030'830	2.8%
Asia	5'911'622	8.2%
Europe	16'528'677	22.9%
Latin America	8'292'139	11.5%
Northern America	3'647'623	5.0%
Oceania	35'881'053	49.6%
World*	72'285'656	100.0%

Source: FiBL survey 2021. Note: Agricultural land includes in-conversion areas and excludes wild collection, aquaculture, forest, and non-agricultural grazing areas.

*Includes correction value for French overseas departments.

Table 4: Organic Agricultural Land (including in-conversion areas) by Region: Growth 2018-2019 and 10 Years Growth

Region	Organic agri. land 2018 [ha]	Organic agri. land 2019 [ha]	1 year growth [ha]	1 year growth [%]	10 years growth [ha]	10 years growth [%]
Africa	1'854'646	2'030'830	176'184	9.5%	958'706	89.4%
Asia	6'364'778	5'911'622	-453'156	-7.1%	3'453'707	140.5%
Europe	15'607'636	16'528'677	921'042	5.9%	6'499'896	64.8%
Latin America	8'008'581	8'292'139	283'559	3.5%	752'496	10.0%
North America	3'342'849	3'647'623	304'774	9.1%	1'174'944	47.5%
Oceania	35'999'373	35'881'053	-118'320	-0.3%	23'735'998	195.4%
World*	71'172'783	72'285'656	1'112'873	1.6%	36'571'729	102.4%

Source: FiBL survey 2021, based on data from government bodies, the private sector, and certifiers. For detailed data sources see annex, page 317

* Total includes correction value for French Overseas Departments.

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Inclusive Agriculture for Smallholder Farmers in Kakamega County

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Abstract

Physical disability is considered a burden in Kenya. Little has been documented about the experiences of people with physical disabilities, particularly those living in rural areas who entirely depend on agriculture as their source of livelihood. Only a few studies focus on the experiences of children with disabilities in terms of violence, stigma, and discrimination and the impact these have on their general health and wellbeing. It is suggested here to achieve human rights to reduce violence, stigma, and discrimination toward people with physical disabilities. There is a need for the implementation of policy and guidelines and the implementation of inclusion in educational and institutional systems. This can be reached if these policies support the rural farming communities where more than 10% of these people live with some form of disability. This study aimed to explore the experiences of farmers living with physical disabilities and pilot a dairy goat program to help these farmers attain financial independence while providing them with healthy diets.

Keywords: Inclusive Agriculture, Disability, Goats

Introduction

For a long time, people living with disabilities have been excluded from many programs and only were brought to the table to make it look like they are involved. Practically not much has been done. Agrokenya's approach to disability inclusion is different. We work with farmers living with disabilities at their level of engagement and seek to improve on what they already are doing, seeing that it is easier to improve on what someone has rather than introduce a new thing altogether.

Agrokenya has an up-and-running dairy goat project purely run by the farmers living with a disability. Why goat farming? Goats are easier to manage and can be handled by farmers living with disabilities comfortably. Their small size means they do not eat a lot, and thus a farmer can easily get food for the animal. Goats are also manageable as they feed on locally available shrubs, which means a farmer can easily get its food. Goat milk is nutritious and fetches a higher value on the market compared to cow milk.

Goats, unlike other animals, are highly resilient (Peacock, 2005) and low-cost animals (Kosgey and Okeyo, 2007). The choice of this animal was influenced by the physical stamina required by the farmers while grazing or attending the animal. Given the nature of the farmers in question, disabled farmers, this animal stood out as the best option. Other than the one highlighted above, the following were the other factors considered while selecting the goats for this project.

- Disabled farmers can easily sustain them.
- The required farmland is much less in comparison to other animals.
- Goats are fairly resistant to diseases.
- They mature faster and can gestate twice a year.
- Goat's milk is highly nutritious, fetches better market prices, and is medicinal.

The overall objective of this project is to provide support to disabled rural farmers to regain their meaningful participation in the agricultural value chain. We prioritize building capacity for disabled farmers, providing essential assistive technologies, and encouraging collaboration.

Methodology



Figure 1: Four Principles of Dairy Goat

This study combined desktop research and key informant interviews of the farmers participating in the dairy goat project within Lubinu Lusheya Ward of Kakamega County. The model is anchored on four fundamental principles.

1. Better health
2. Improved incomes
3. Better engagement
4. Improved yields

A revolving goat fund is maintained where a farmer is registered as a group member and receives a goat. The farmer donates two calves within one year, which are handed over to another farmer. After that, the original goat remains with the farmer. During this period, the farmer is encouraged to consume goat milk and use the manure on the farms.

Results and Conclusions

Over 40 plus farmers have benefited from this program with just eight goats initially. More disabled farmers have been gathered into a joint interest group of Mumias East Disability Group to champion their needs.

Disability has for a long time been viewed as a sort of inability. Most families have ended up neglecting PWDs and not offering them a chance to access education, training, and skills transfer to empower themselves economically. They have also been denied the right to own land, which is a primary factor of production. Thus, this hinders their ability to participate in productivity actively. They also face infrastructural barriers when they seek essential services like healthcare.

The Agrokenya dairy goat project has benefited over 40 disabled rural farmers. These farmers have found new meaning and have rejuvenated their efforts in becoming productive members of society. Farmers are more energized, hopeful, and determined to engage in farming to gain financial independence and earn decent incomes from goats.

The project attracts attention from different quarters by its angle of working with farmers living with disabilities.

We have gotten a boost from KALRO Naivasha, who brought a Toggenburg buck to enable the members to upgrade the breed, thus improving milk yield.

The Vihiga County government has also expressed interest in Agrokenya to scale this project nearby.

Recommendations

Preliminary findings of this project demonstrate the positive impact this project has had on the disabled farming communities in western Kenya. Based on the success stories from the participating farmers, we would like to vouch for programs that can help scale this project to reach out to more disabled and even non-disabled farming communities. In particular, we recommend

- partnerships with MMUST for a breed upgrade, acquisition of best practices, and CSR projects with the farmers living with disabilities,
- research on the possibility of including goat and other animal waste in biogas production and installing the same in some farmer homes,
- boosting the farmer's income by purchasing goats and milk from them,
- teaching the farmers on value addition to goat milk,
- through the introduction and use of agro-apps to connect farmers with other farmers and the markets,
- prosthetics for our farmers living with disabilities, among other supportive devices, what will be quite crucial in supporting this project.
- acquisition of land for Agrokenya to produce goat feed as well as land for organic farming as an income generating measure for the sustainability of the project.

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Clean Water and Sanitation Services Crisis in Kakamega County, Kenya – Development of Ceramic-based Potable Water Purifier

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Abstract

This is a report and the recommendations on the actualization of the work that was aimed at solving a clean water problem in rural Kenya, and a case study of what can be applied to Kakamega County. The devised project is a continuation of the work that was partly done by Sona Awasthi, an MSc Student at Technische Hochschule Brandenburg University of Applied Sciences, titled 'Development of Water Treatment Techniques for Kenya,' and disseminated through a thesis that was developed in cooperation with Masinde Muliro University of Science and Technology (MMUST) in Kakamega, Kenya, within the DAAD Project ProUniEdu-WeK. This report provides an overview of the situation on the provision of clean water in Kenya and narrows it to Kakamega County. With a population of about 50 million, 41% of Kenyans rely on unimproved water sources, streams, ponds, and rivers, while about 48% of Kenyans lack access to essential sanitation solutions. These challenges of clean water provision and sanitation are especially evident in rural areas and urban slums, where people often cannot connect to piped water infrastructure. This report provides progress on the ceramic filter water purification project within the ProUniEdu-WeK project. In the project, developing a ceramic-based potable water purifier uses the nano-material principle where Ag-Ti/Mg nano-composite is embedded in the ceramic filter to remove toxic pollutants and pathogens from water. Thus the production of potable water is clean for domestic use. The project has registered some achievements. So far, apart from an MSc degree award, a doctorate (Ph.D.) student is working on the project as an output.

Furthermore, the project has attracted seed money (400000 KES) from the Masinde Muliro University of Science and Technology (MMUST) Research Funds. In addition, the Ph.D. student also obtained International Foundation for Science (IFS) funds to help in her work. The ceramic filter prototype is currently in development and is incubated at MMUST. The project's end product will be the commercialization of the portable water purifier gadget that will significantly contribute to solving the water crisis, especially in rural Kenya. For the future, we seek to partner with interested researchers, institutions, or organizations that have an interest in water provision and access, environmental sustainability and conservation, water infrastructural support, sanitation and hygiene, water commercialization/ financing, and policy. Future water-related projects are envisaged to be carried out within Kakamega County.

Keywords: Water Purification, Water Purifier, Quality of Water

1. Introduction

Currently, one out of four people, approximately 2 billion people worldwide, lack safe drinking water. According to the WHO/UNICEF (2021) report, almost half of the global population, 3.6 billion people, lack safe sanitation, and 494 million people still practice open defecation. The Government of Kenya's commitment to upholding the right to water and sanitation is enshrined in Article 43 of the constitution, which guarantees the right of all Kenyans to clean and safe water in adequate quantities, and to reasonable standards of sanitation. Internationally, the right to safe and clean drinking water and sanitation is recognized as a human and is inextricably linked to the rights to health, adequate housing, and food. Sustainable Development Goal 6 on water and sanitation (SDG 6) seeks to ensure safe drinking water and sanitation for all. In particular, SDG 6 aims to achieve universal and equitable access to safe and affordable drinking water by 2030. This right is essential for the full enjoyment of life and all human rights globally. The right to water is part of the right to an adequate standard of living.



Photo: Walking long distances to get water, which may not even be clean (Ngusale, n. d.)

1.1 Availability and Sources of Water

General water and sanitation services are devolved to county governments in Kenya. The county governments have established companies or cooperated as water service providers. The water is mainly abstracted from various water source points and piped to human settlements. Various water regulatory authorities in Kenya guide, direct policies and implement the different aspects of water and sanitation. Water sources are varied in Kenya. For example, during the dry season, the majority of residents (55 %) rely on private water suppliers (water kiosks, boreholes, and water tankers), while 42 % of the residents use the publicly-regulated water supply (public taps/standpipes, piped household water in compound) and 2 % use unimproved sources like rainwater collection, rivers or ponds (WHO/UNICEF 2020). 35% of respondents primarily use the publicly

regulated water supply in the rainy season, while 33% rely on private water suppliers, and 16% use unimproved sources. The increase in rainwater collection accounts for the steep drop in the use of private water suppliers and the slight decrease in the use of the publicly regulated water supply (WHO/UNICEF 2020). These findings indicate that only a minority of respondents in informal settlements have regular access to public water supply, which is regulated, and less costly. The figure below shows the primary water sources during Kenya's dry and rainy seasons.

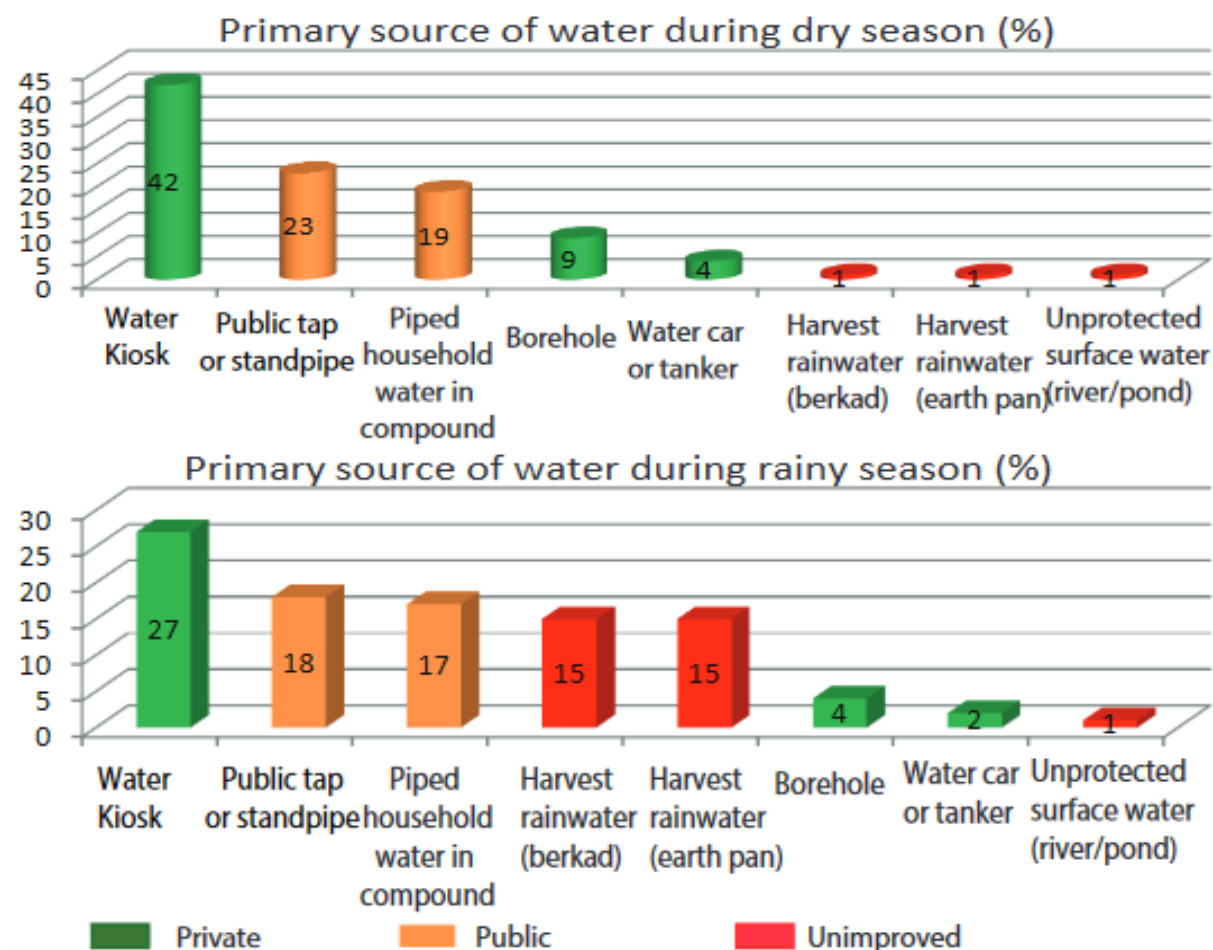


Figure 1: Availability and Source of Water during the dry Season and wet Season in Kenya (Source: Percentage Urban Households by Main Source of Water, 2013)



Photo: People wait to buy water from a local vendor. Report by Kanyiri Wahito, on Daily Nation newspaper in Kenya (Kenyan Slums Hit By Severe Water Shortages, n. d.)

1.2 Quality and Acceptability

According to the United National Human Rights, General Assembly Resolution 64/292 & Committee on Economic, Social and Cultural Rights, General Comment 15, the water must be acceptable in colour, odour, and taste. It must be free from microbes and parasites, chemical substances, and radiological hazards that constitute a threat to a person's health. These aspects of quality and acceptability are often overlooked, and priority is usually given to water provision only. Water providers must ensure strict adherence to regulation and monitoring programs that ensure the provision of quality water. Poor sanitation in urban and rural areas is a significant cause of low-quality water.

1.3 Sewerage System

In Kenya, sewerage covers only 3 million Kenyans. Kenya sanitation coverage requires access to clean water, but only 18 million Kenyans in rural and urban areas still have no access to water. The sewerage system coverage is at 16%, and approximately 70% of urban households use onsite sewerage. According to the Kenya National Bureau of Statistics (KNBS), about US\$85 million is required to 'fill funding gap', so it has to enhance sewerage coverage in Kenya to acceptable levels significantly. On the other hand, Poor sanitation costs Kenya 27 billion Kenyan Shillings each year, equivalent to US\$324 million,* according to a desk study carried out by the Water and Sanitation Program. This sum is the equivalent of US\$8 per person in Kenya per year or 0.9% of the national GDP, according to the Water and Sanitation Program 2012. Figure 2 shows the Kenyan sanitation coverage.

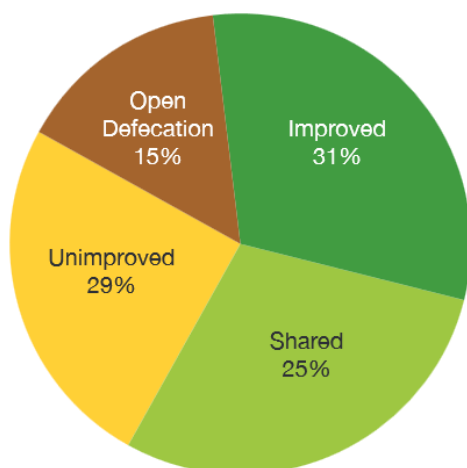


Figure 5: Kenya Sanitation Coverage (Source: Water and Sanitation Program (WSP), 2012)

1.4 Status at Kakamega County

In 2013, and as per the 2010 constitution, the elected government committed itself to a rapid transfer of devolved functions to the counties, including funding allocation. This is because water and sanitation services were devolved to the county governments. Kakamega County now needs to ensure the financing of both development and recurrent expenditures related to the water and sanitation services. According to KNBS and SDI (2013), in Kakamega County, 61% of residents use improved water sources, while the rest rely on unimproved sources. Kakamega County loses 943 million KES each year due to poor sanitation. It includes losses due to access time, premature death, health care costs, and productivity. This estimate does not include some expenses that could be significant (such as water pollution and tourism) and is therefore likely to underestimate the actual cost of poor sanitation. Figure 3 shows the state of sanitation in Kakamega County, while the following photo depicts a water kiosk. Figures 4-6 show the sources and distribution of water in Kakamega County.

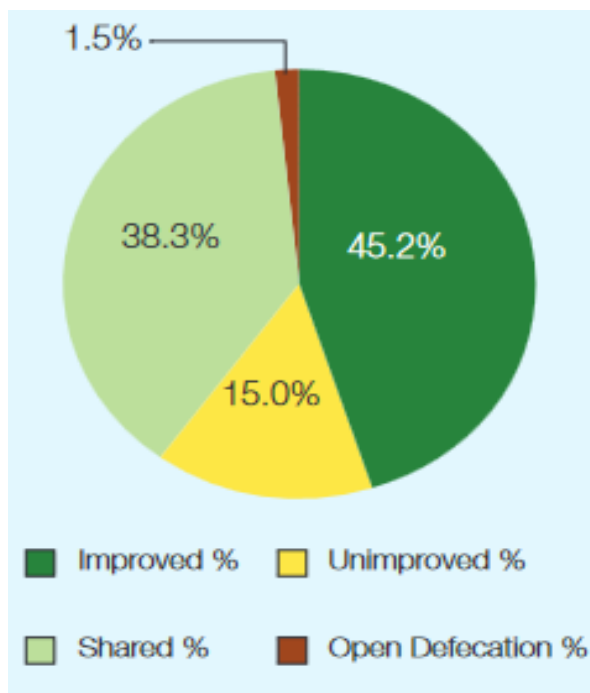


Figure 6: The State of Sanitation in Kakamega County (Source: Water and Sanitation Program (WSP), 2014)



Photo: A lady in Kakamega County fetches water from a water kiosk operated by Kakamega County Urban Water and Sanitation Corporation (KACUWASCO). Note that mobile technology is also used in payments (USAID, 2020).

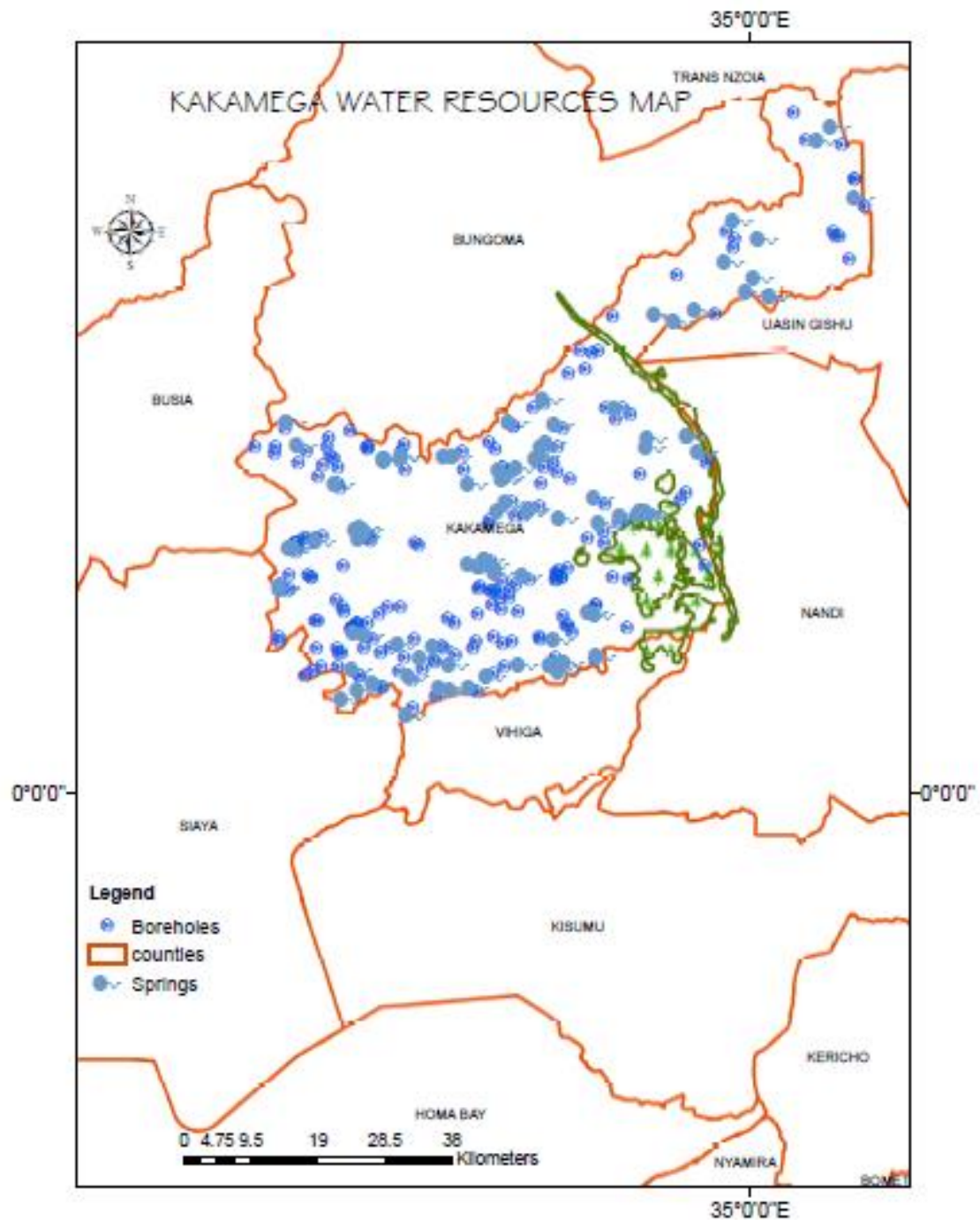


Figure 4: Springs and Boreholes Location in Kakamega County (Source: County Government of Kakamega, n. d.)

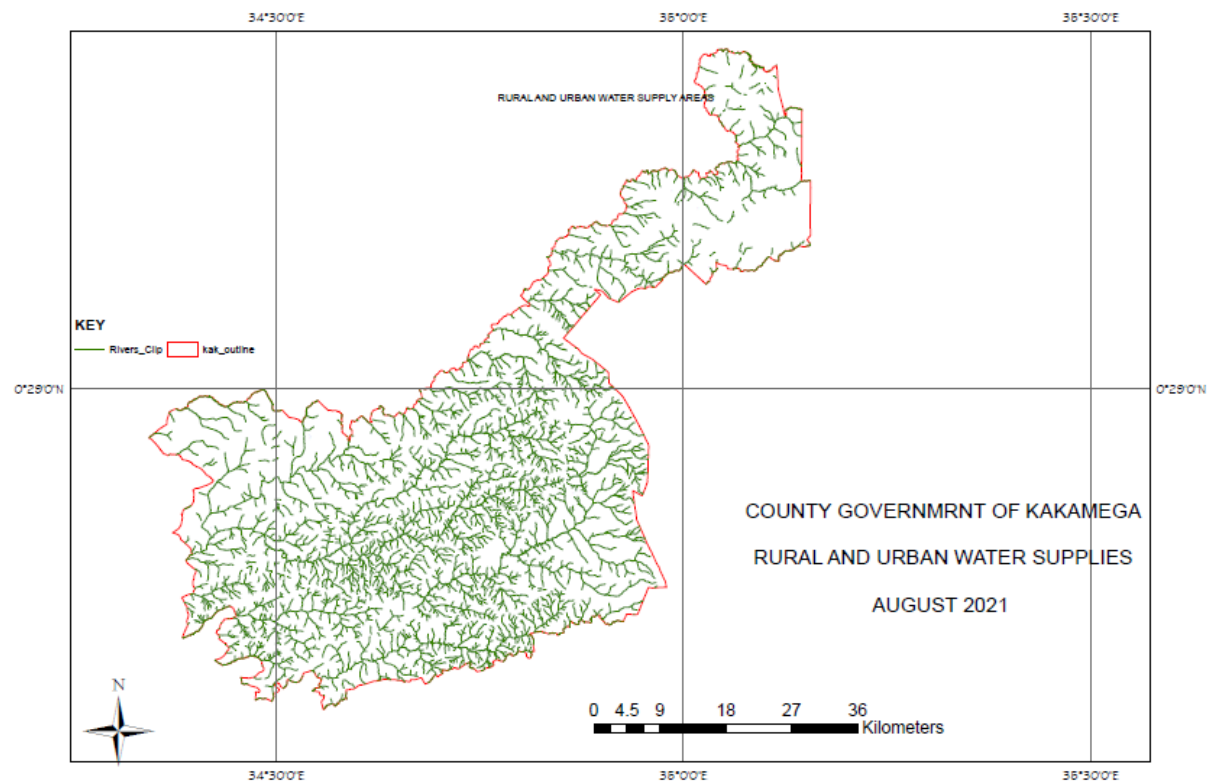


Figure 5: Streams and Rivers in Kakamega County (Source: County Government of Kakamega, n. d.)

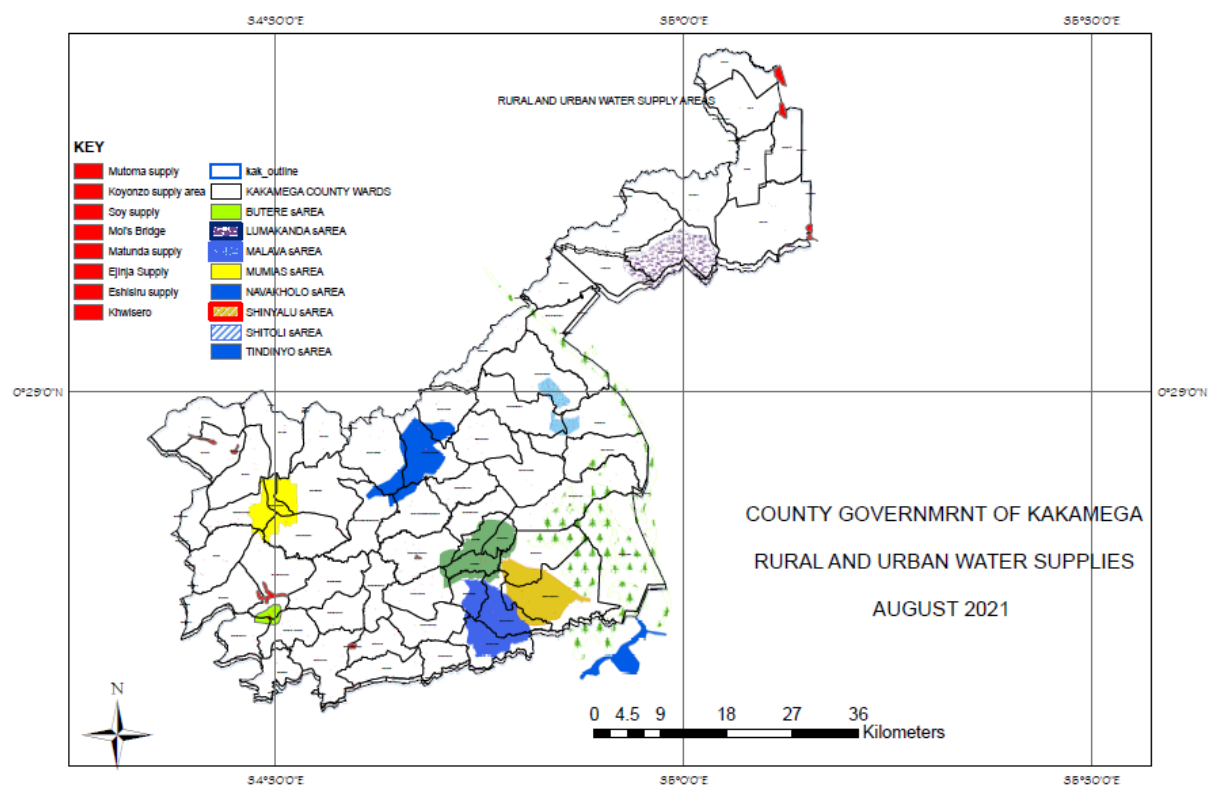


Figure 6: Rural and Urban water Distribution in Kakamega County (Source: County Government of Kakamega, n. d.)

2. Development of Ceramic-based Potable Water Purifier to Enhance the Health of the Local People in Kakamega

Ceramic water filters are of various shapes and sizes that obstruct multiple microorganisms. Their manufacturing process is simple, inexpensive, and the needed raw materials are locally available. The current project was inspired by; the need for clean and reliable drinking water and the commercialization of potable water purifiers. The traditional African water pots concept has been used to store drinking water for centuries. Field trials in Cambodia showed a 46% reduction in diarrheal disease. 95.1% average (and up to 99.99%) reduction of E.coli in drinking water (Brown and Sobsey, 2006) and 90-99% reduction in viruses (Brown, 2007). The key aspect behind the proposed ceramic water purifiers is the micropores in the ceramic membrane, which has been reported to filter out harmful bacteria, protozoa, and organic materials with up to 99%. Nanotechnology specifically uses silver-based nanoparticles to increase the efficiency of ceramic filters. The pathogens that can be removed effectively from water are the following bacteria: *Campylobacter jejuni*, *C.Coli*, Pathogenic *E.coli*, *Salmonella Typhi*, other *Salmonella Shigella* spp. *Vibrio cholerae* *Yersinia enterocolitica* *Pseudomonas ae.* *Aeromonas* spp. Viruses: Adenovirus Polio, Virus Hepatitis A, Virus Hepatitis Non-A, Virus Enterovirus Norwalk, Virus Norwalk-Like-Viruses (NLV) Rotavirus. Protozoa: *Entamoeba histolytica* *Giardia* spp. *Cryptosporidium* spp. The filters can remove chemical pollutants from the water, apart from pathogens. Figure 7 and the following photos illustrate the idea behind the project.



Photo: The Principle of Traditional African Clean Water Storage Pot enhancement by Nanotechnology

To circumvent this limitation, nanotechnology, specifically using silver-based nanoparticles to increase the efficiency of the ceramic filters, has greatly been utilized (Rayner, 2013; Lantagne, 2001; Pradeep & Anshup, 2009; Hagen et al 2018). For instance, AgNP and silver nitrate (AgNO_3 , Ag^+) have been shown to enhance the filtration of both bacteria and viruses. This is commonly done by either brushing or dipping the filters in a solution of colloidal silver nanoparticles or an Ag^+ (Pradeep & Anshup 2009). The two mechanisms of microorganism disinfection by ceramic water filters are (i) removal by size exclusion or adsorption (ii) inactivation of pathogens by silver nanoparticles in the ceramic filter.

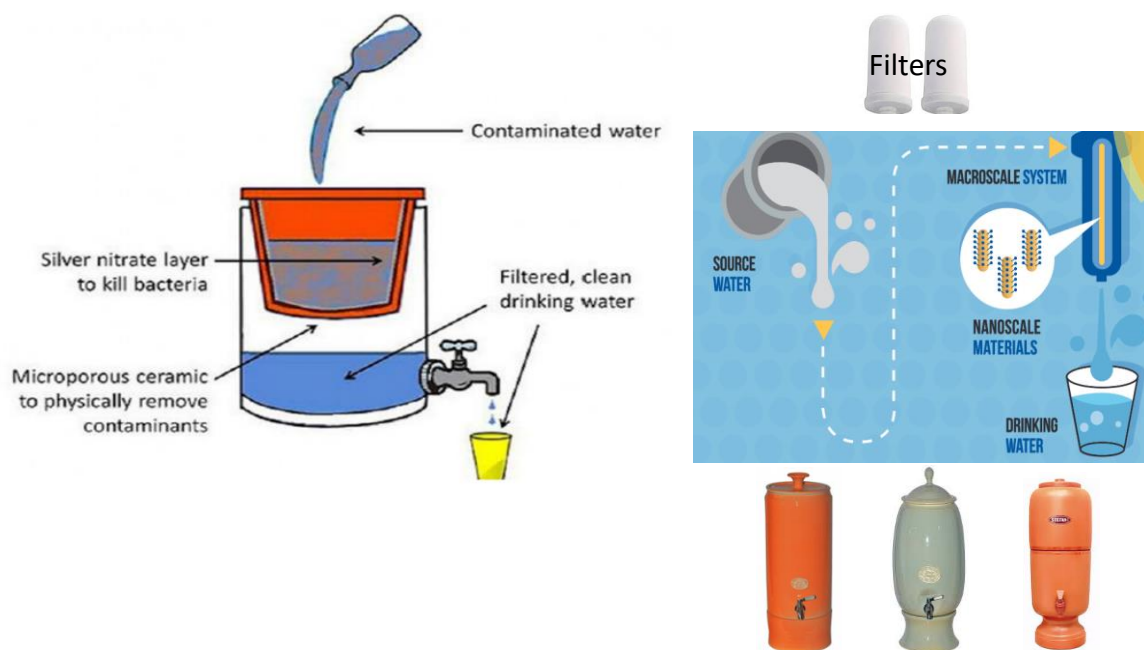


Figure 7: Ceramic Water Purification: enhanced with nano-inorganic sorbents (Source: the Water Technology spouts of water 2021)

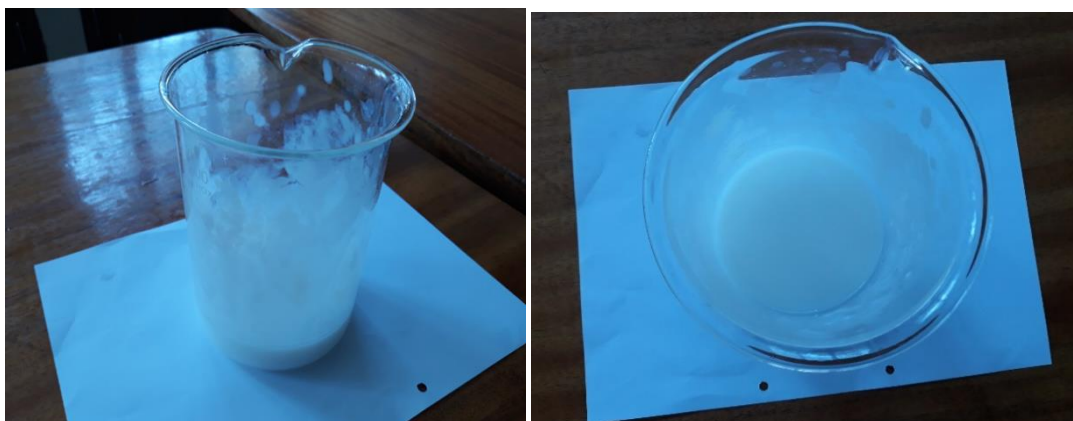


Photo: Preparation of Ag-Ti/Mg nanoparticles composite (Source: this study)



Photo: Development of the Filter Prototype for the Project (Source: this study)

3. Conclusion, Recommendation and Way Forward

Adapting practical-oriented education is vital in realizing the 2030 Agenda for Sustainable Development Goals (SDGs). There must be an intentional paradigm shift in our education curriculum that aims to empower students and local communities to be able to solve problems that affect them and create wealth. Undergraduate and postgraduate programs in tertiary education should be geared towards practical teaching. As a start, this report suggests a seminar or a significant water workshop at Kakamega County or at MMUST with interested partners and stakeholders whom we shall identify to educate water stakeholders on current water treatment and supply technologies that can be suitable for the rural populations. In the future, we also seek to research and develop other water treatment technologies that use principles such as; water purification uses gravity to push water through a membrane or filter, and ultra or micro-filtration.

Furthermore, we are interested in solar distillation, solar water disinfection, and the use of adsorbents and cheap reverse osmosis. More extensive projects suitable in the rural area will be welcomed as well. Examples are solar or a hybrid system to pump groundwater to households. Exchange programs that involve water technology experts or engineers from Germany in organized workshops with students, lecturers, and Kakamega county staff are recommended for technology and knowledge exchange.

There is a need for more partners to join the current stakeholders, researchers, institutions, or organizations interested in working with rural communities in matters related to clean water provision. The themes for the future proposed collaborations are;

- i. Education and awareness creation to students, local community-based organizations (CBO), and water users.
- ii. Technology transfer
- iii. Water provision and access;
- iv. Water infrastructural support;
- v. Sanitation and hygiene;
- vi. Water commercialization/ financing, and policy;
- vii. Environmental sustainability and conservation;
- viii. Water commercialization/ financing, and policy;

4. Pilot Project Proposal for 100 Households at a Local Community in Rural Kakamega

We can do some research projects for water purification; the area is within a four-kilometer radius, an ideal location that can be used as a model. The proposed pilot study is recommended to work with IPCO, a local CBO, for youth and women situated within an area with a health hospital, high school, three kindergartens, and a primary school with no permanent residence water solution. We are looking for partners to start this pilot project. The proposed project is a hybrid solar water pump (see figure 8) and a mini water treatment plant within the pilot study area. With these infrastructures, the proposed study area has the potential to be an example of how integrated technologies can be used to

serve local communities in the provision of water, energy, and other needs. Examples of the technologies that can be applied for clean water provision are water purification using catalysis, gravity-based water to push water through a membrane or filter. More examples are ultra or micro-filtration, solar distillation, solar water disinfection, use of adsorbents, and cheap reverse osmosis.



Photos: I installed a water hand pump project for children at a rural school together with Prof. Dr. Rolf Dieter Wilken of Gutenberg-Universität, Mainz, Germany, and Dr. Francis Orata Omoto in 2010 proposed CBO pilot project area. (Source: Author's photos)

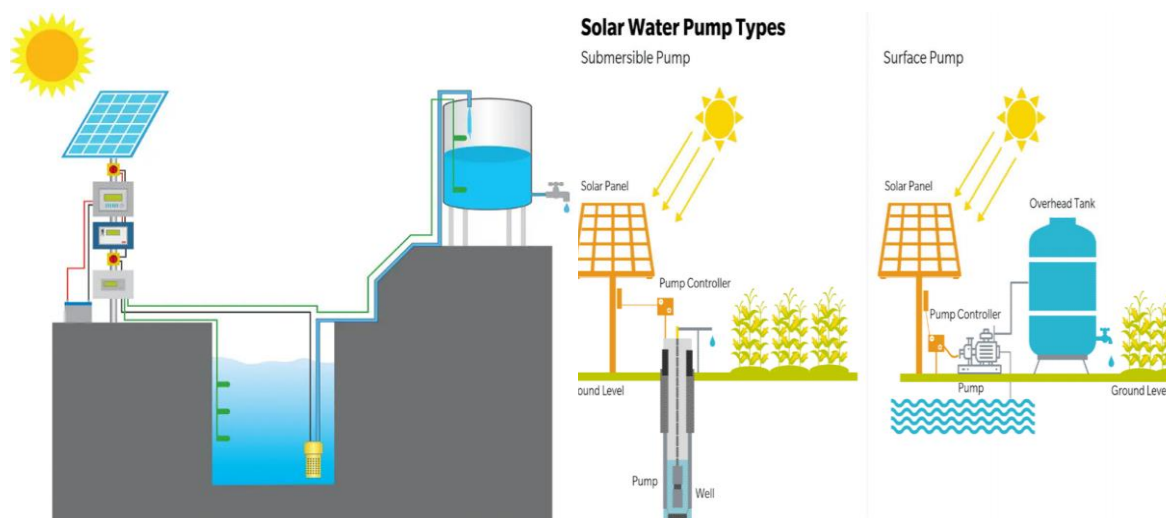


Figure 8: The Model of the Pioneer Project that we can partner, partially supported by the county government (Source: Solar Magazine, 2020)

Acknowledgment

I acknowledge the ProUniEdu-WeK project sponsored by DAAD. Prof. Dr. Dietmar Wikarski, the project leader. The expertise of Prof. Dr. Reiner Malessa. The Masinde Muliro University of Science and Technology and the Pure and Applied Chemistry Department at MMUST. The Local CBO, IPCO. The county government of Kakamega, Kakamega County Rural Water and Sanitation Company (KACRWASCO).

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Training on Catalysis and Industrial Chemical Processes for Practice-orientated University Education in Western Kenya

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Abstract

In line with promoting practice-oriented university education, selected staff members and students are drawn from the Department of Pure and Applied Chemistry of Masinde Muliro University of Science and Technology (MMUST) in Kenya have been trained on catalysis and industrial chemical processes. This training has enhanced their knowledge of current global trends on catalysis and industrial chemical processes and promoted industrial linkages between MMUST and industries in Kenya and cooperation between MMUST and research centers and universities in Germany.

Keywords: Catalysis, industrial chemical process, university training

1. Training on catalysis and industrial processes

One of the goals of the Practice-orientated University Education in western Kenya (ProUniEdu-WeK) project is to promote practical-oriented university education in Kenya, which is closely connected with the industry. In manufacturing industries, chemical processes and catalysis are vital in converting raw materials to finished products and processing waste materials to valuable products. Catalysis plays a pivotal role in most industrial chemical processes. It enhances the efficiency of desired reaction paths by accelerating their reaction rates. Therefore, it is essential to develop sustainable products from natural resources and conversion of waste materials to useful or less toxic products. Indeed, catalysis is the heart of industrial chemical processes (Dev *et al.*, 2018; Durrant, 2020; Védrine, 2018).

Two one-week-long training workshops were held to acquaint members of staff and students from the School of Natural Sciences (SONAS) at MMUST with the current global trends in industrial chemical processes and catalysis. The first training was held in January 2019, where 10 staff members and 15 students were trained. After that, a visit to Orbit Chemical (*Orbit Chemical Industries Ltd*, 2008), the leading manufacturing industry, was conducted (see last Photo). This industry is key in converting raw materials to finished products and applying catalysis in most processes. The participants learned about the industrial chemical processes and catalysis in producing soaps and detergents, agrochemicals, sulphonation, and plastic packaging, among others. An industrial linkage was established between MMUST and the industry.

The second training workshop was held in January 2020. Similar to the first workshop, 25 participants were trained, consisting of 10 staff members and 15 students.

After the training, an industrial visit was made to the Kenya Industrial Research and Development Institute (*Home - Kirdi, 2021*), an institute mandated by the government of Kenya to undertake multidisciplinary research and development of industrial and allied technologies. So far, 50 participants (including 20 staff members and 30 students) have been trained on catalysis and industrial chemical processes. The photo shows one of the training sessions at MMUST.



Photo: Catalysis and Industrial Chemical Processes Training Session (Gershom Mutua)

After each training session, the successful participants were awarded certificates, as shown in the photo below.



Photo: Award of certificates to a successful participant (Gershom Mutua)



Photo: An industrial visit to Orbit Chemicals in Kenya in January 2019 (Gershom Mutua)

In addition to the training conducted in Kenya, training on biomass conversion to energy and conversion of waste to valuable products was conducted at ATB-Potsdam (*Leibniz-Institut für Agrartechnik und Bioökonomie*, 2021), Germany, where one of the authors underwent a 3-week internship program. This was necessary to transfer his knowledge to other members of staff and students of MMUST. The group received a laptop and a

projector through the sub-award agreement between Brandenburg University of Applied Sciences (BUAS) and MMUST, funded by DAAD to enhance further training. This equipment has been used for training purposes through seminars and workshops.

2. Output of Training on Catalysis and Industrial Chemical Processes

The training enabled the knowledge of catalysis and industrial chemical processes to be deepened. In addition, the employees and students at MMUST received an insight into current trends in catalysis and industrial chemical processes. A review of the curriculum of the Industrial Chemistry program of MMUST to include current trends in catalysis and chemical processes has been done. Moreover, the enhanced industrial linkage between MMUST and different industries in Kenya and Germany has been achieved. In addition, the program expanded the cooperation between Kenyan and German scholars.

3. Prospects of the Project

It is recommended to continue with the training workshops on catalysis and industrial chemical processes to train more people. The upcoming training workshops should include simulation of industrial processes to link computational modeling and real industrial chemical processes. Mini-reactors should be availed to demonstrate industrial chemical processes and catalysis.

4. Acknowledgements

Firstly, we acknowledge Prof. Dr. Dietmar Wikarski, the project leader of ProUniEdu-Wek, for his outstanding leadership. Secondly, we are grateful to Prof. Dr. Reiner Malessa for conducting the training on catalysis and industrial chemical processes. Furthermore, we recognize MMUST and THB for their support and offering an enabling environment for the project to be executed. In addition, we express our sincere gratitude to DAAD for their financial support, KIRDI, and Orbit Chemicals Kenya for permitting us to visit their industries.

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Impact of the Number of Turbine Blades on the Efficiency of Cross-Flow Turbine for Low Head, Low Flow: Finite Elements' CFD Analysis

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Abstract

A cross-flow turbine can attain an efficiency of 90% if further investigations on major geometrical parameters like the number of runner blades can be conducted. The selection of several blades is crucial, yet no fundamental theory guides its selection. In addition, none of the experimental studies conducted have achieved this, besides not explaining the effects of these parameters on the turbine efficiency. Therefore, this paper aims to suggest a fundamental theory for selecting many runner blades for a high-efficiency cross-flow turbine and numerically propose a suitable number of blades for a high efficient cross-flow turbine for low flow head and velocity. To attain this, numerical computation based on Reynolds-averaged Navier-Stokes (RAN) simulation was achieved by SolidWorksTM CFD and validated by ANSYSTM CFD. Four runners with different blades were modeled and simulated while holding other geometric parameters constant. The Gauss-Newton algorithm achieved iteration for the theory. The simulation results revealed that a cross-flow turbine with 30 blades recorded the highest efficiency of 91%. The runner's efficiency increased with an increase in the number of blades for the blade range of 16 to 30. Also, a typical theory for selecting the corresponding number of turbine blades for the desired efficiency in a low head, low-velocity run-off flow is proposed.

Keywords: Number of Blades, cross-flow turbine, Efficiency, Finite Element Method, CFD

1.0 Introduction

Comparative study between small-hydro-electric power plants (up to 10 MW capacity) and micro-hydro-electric power plants (up to 100 KW capacity) reveals that the former one is more capital intensive and involves major political decisions causing difficulties in different implementation phases. On the other hand, micro-hydro-electric power plants are low-cost, small-sized. They can be installed to serve a small community making its implementation more appropriate in the socio-political context. Many of these systems are "run-of-river," which does not require an impoundment. Instead, a fraction of the water stream is diverted through a pipe or channel to a small turbine, which sits across the stream (Nasir, 2014).

The deficit in energy requirements needs identification and maximum use of available renewable energy resources (RERs), with micro-hydropower as the major (74%) energy source due to the many small rivers, tributaries, and distributaries that can be utilized to provide reliable off-grid power. However, micro-hydro is a site-specific resource

dependent on flow characteristics and turbine design parameters. Additionally, most existing small hydroelectric power (HEP) suffer turbine speed fluctuation during load variations (Mbaka and Mwaniki, 2016). Specifically in Kenya, most of the rivers in the high-power demand remote areas have extremely low heads that need a proper design optimization of the cross-flow turbines for maximum efficiency. Thus there is a need to model and simulate micro HEP to realize optimum design consideration for off-grid domestic power capacity to optimize the number of blades to increase the efficiency. The number of blades in a micro-hydro turbine is among the major geometric parameters that affect cross-flow turbines' performance. Much research has been done on the same but focussing on internal flows through nozzles, yet in a real sense, the turbine experiences external flow while floating on the water. The blades convert the kinetic energy of water to the turbine's mechanical energy.

In particular, the advantages that micro-hydro-electric power plant has over the same size wind, wave, and solar power plants are:

- High efficiency (70-90%), by far the best of all energy technologies.
- High capacity factors (> 50%) compared with 10% for solar and 30% for wind power plants.
- A slow rate of change: the output power varies only gradually from day to day, not from minute to minute. The output power is maximum in winter.

According to Adhikari and Wood (Adhikari and Wood, 2018), a cross-flow turbine can attain an efficiency of 90% if further investigations on major geometrical parameters like the number of runner blades can be conducted. None of the experimental studies conducted have achieved this, besides not explaining the effects of these parameters on the turbine efficiency. Thus, a strong justification for adopting a computational study on the appropriate number of runner blades that will be optimum for the desired design selection. They recommended a thorough numerical study on establishing a theory that will help select an optimum number of blades in a cross-flow turbine for high efficiency of at least 90%, as it is the case for other low head turbines. Also, Adhikari (Adhikari, 2016), Acharya (Acharya et al., 2015), and Sammartano et al. (Sammartano et al., 2016) noted that the selection of the number of blades is very crucial. However, there is no fundamental theory that guides its selection. This paper, therefore, aims at suggesting a fundamental theory for the selection of several runner blades for a high-efficiency cross-flow turbine.

According to Khosrowpanah (Khosrowpanah, 1984), the experimental study of cross-flow turbine performance by varying the number of runner blades showed that it affects the turbine efficiency. In a range of experiments with runners of 15 to 20 blades, a blade number of 15 was identified as the optimum. In another experiment by C. Pereira and J. Borges (Pereira and Borges, 1996), a range of 10 to 25 runner blades of cross-flow turbine was experimentally tested. However, the conclusion was that the influence of the blade number was not clear. Olgun and Ulku (Olgun and Ulku, 1992)) found that 28 blade runner was the optimum compared to 20, 24, and 32 blades. However, Desai and Aziz

found that for a runner with a blade range of 15 to 30, the higher the number of blades, the higher the turbine efficiency.

A recent modeling and simulation study was done by Sayeed (Saeed, 2014)) where he concluded that the runner's efficiency increased with a number of blades for a blade range of 15 to 30. However, between 30 and 40, the efficiency declined. Nevertheless, this study was treated as an internal flow through nozzle inlet and outlet with relatively few meshing elements. The summarised review highlights a great need to further investigate the effect of the runner blades on the turbine's efficiency and design its selection criteria.

1.1 Cross-Flow Turbine Theory

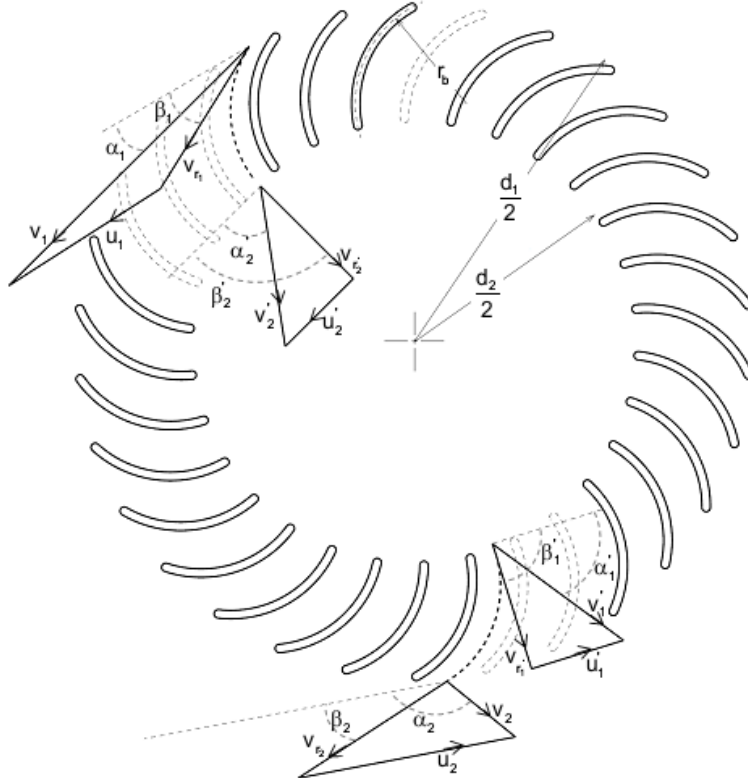


Figure 7: Schematic cross-sectional view of the cross-flow turbine (Adhikari and Wood, 2017)

A cross-flow turbine is a low head turbine considered for adoption in remote power systems due to their simple design and low cost compared to other low head turbines such as Pelton, Turgo, and Francis. It has a typical efficiency of 70% to 85%. However, this efficiency is relatively lower than that of other low-head turbines, which record up to 90%. The turbine's efficiency is directly related to the power output and the design characteristics of the turbine feature. Therefore, the study aims at synthesizing the major key design features of the cross-flow turbine to determine their optimum value that will enhance optimum efficiency (Adhikari and Wood, 2018).

Based on Adhikari and Wood (Adhikari and Wood, 2018), the key geometrical parameters that affect the efficiency of a cross-flow turbine are inner to the outer radius (R_2/R_1), a number of blades (N), outer blade angle, inner blade angle, and blade thickness. To attain optimum efficiency, however, it has been found that outer blade and inner blade

angles must be close to each other to avoid fluid separation on the blades. A similar attribute is on the blade thickness, which should be of small thickness for maximum efficiency. Hence the number of runner blades dominates the essential geometrical feature to be explored exhaustively (Adhikari and Wood, 2017). Hence the aim of this study.

From Figure 1, the flow passes through the runner in two stages, namely the runner's inlet and the runner's outlet. In both stages, substantial energy conversion occurs, which depends on the predominant geometrical features, which is the number of runner blades.

The input power is given by:

$$P_{input} = \gamma Q H \quad \dots\dots\dots \text{Equation 1}$$

Where: γ = Specific weight of water, Q = flow rate, H = net head

Output power:

$$P_{output} = T \omega \quad \dots\dots\dots \text{Equation 2}$$

Where: T = runner torque, ω = rotational speed of the runner (rad/s)

The runner efficiency = P_{output} / P_{input}

$$\beta_1 = \tan^{-1} \left(\frac{U_r}{U_\theta - \omega R_1} \right) \quad \dots\dots\dots \text{Equation 3}$$

U_r and U_θ are radial and tangent components of runner velocity (Adhikari and Wood, 2017)

Assuming that there is no difference in blade angle in the second stage, the optimum runner angular velocity ω , can be obtained by

$$\omega_{max} R_1 = \frac{U_0}{2} \left(1 + \frac{h_0^2}{R_1^2 \theta_s^2} \right) \quad \dots\dots\dots \text{Equation 4}$$

Desai and Aziz (Desai and Aziz, 1994, 1994) experimented on a cross-flow turbine to investigate the effect of specific parameters on its efficiency. It entailed the design and fabrication of models of cross-flow turbines with a variety of several runner blades, inner to outer diameter ratios, and angles of attack. Three nozzle shapes and 27 runners were tested. It was found that the cross-flow turbine efficiency increased as the number of runner blades increased from 15 to 25. This contradicts Khosrowpanah et al. (Khosrowpanah et al., 1988)) experiment, which showed that the optimum efficiency is when the runner is of 15 blades.

Olgun and Ulku (Olgun and Ulku, 1992) investigated the performance of the cross-flow turbine by varying the number of the runner blades, the inner to outer diameter ratio, and the nozzle opening with varying heads. It involved designing and fabricating an experimental rig of the cross-flow turbine. 2 nozzles and 13 runners were tested. The nozzles and the runner blades had the exact width of 114mm, runner outer diameter of 170mm, blade inlet, and outlet angles of 30° and 90°, respectively. The numbers of runner blades were 20, 24, 28, and 32 blades. This experiment showed that the maximum efficiency recorded in this experiment was about 73%, using a runner with 28 blades. Though this results contrast those of Khosrowpanah et al. (Khosrowpanah et al., 1988).

2.0 Methodology

The methodology adopted was the numerical computation that gave performance prediction of different chosen turbine configurations based on Reynolds-averaged Navier-Stokes (RANS) Simulation. This was achieved by SolidWorks™ CFD and validated by ANSYS™ CFD. The test installation had no guide vanes and nozzle but was considered to operate on low velocity and low head streams most predominantly available in practical remote setups. Iterations for the theory were achieved by the Gauss-Newton algorithm using Minitab™.

To achieve this the turbine runner was modelled in SolidWorks™ with the following geometric parameters considering the previous optimum values:

Geometrical parameter specification

Number of blades	$n_b = 16, 23, 30, 37, 44$
External diameter	$d_1 = 500\text{mm}$
Diameters ratio	$d_2/d_1 = 0.6$
Angle of attack	$\alpha_1 = 0^\circ$
Inlet blade angle	$\beta_1 = 150^\circ$
Internal blade angle	$\beta_1 = \beta_2 = 90^\circ$
Outlet blade angle	$\beta_2 = 29^\circ$
Blade thickness	$t_b = 5\text{mm}$
Blade radius of curvature	$r_b = 221.56^\circ$
Shaft (axle) diameter	50mm
Net head	1m
Velocity	1m/s

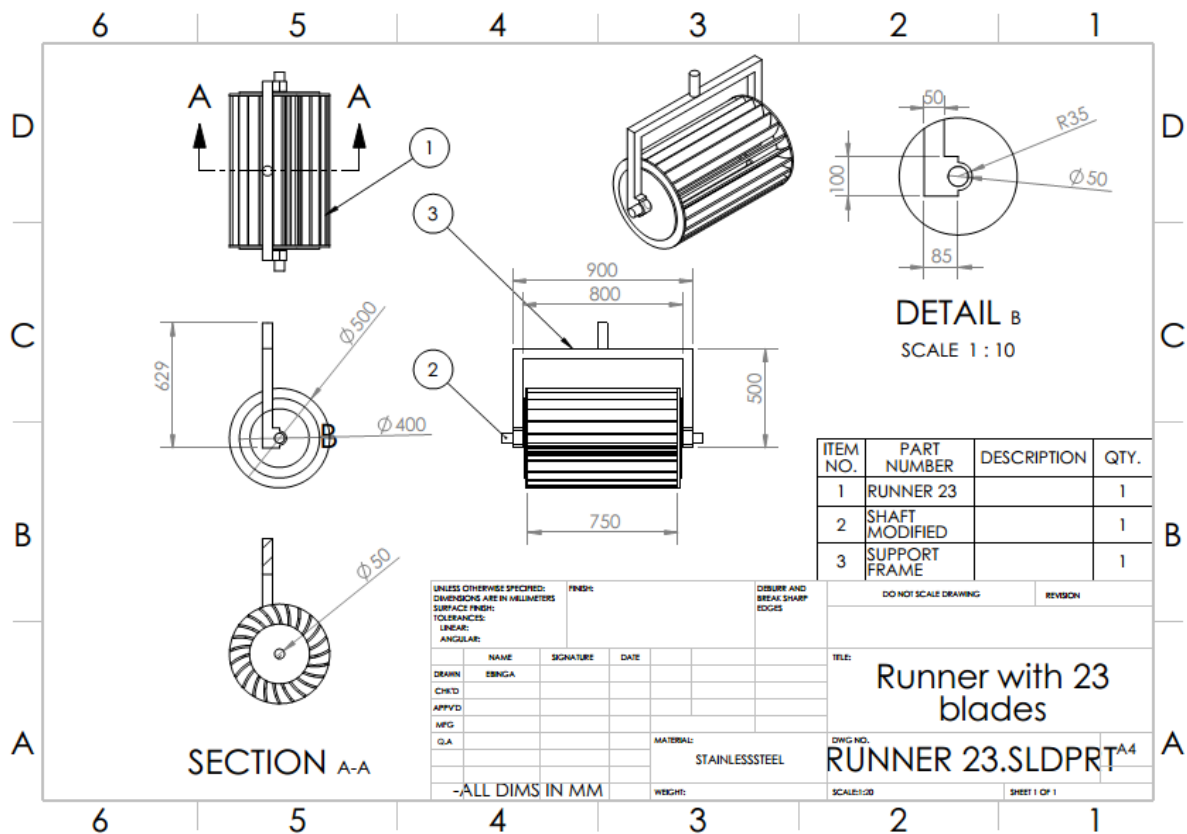


Figure 8: Design drawing of the 23 blade cross-flow runner

The models were then simulated in FlowXpressTM with the above geometrical parameters interchangeably and the results of the number of blades and their corresponding torque recorded.

The runner efficiency of the corresponding number of blades runner was calculated from their corresponding torque and recorded results.

The observed number of blades versus the corresponding efficiency was iterated to get the best non-linear relationship for cross-flow turbines adoption.

2.1 Computational Domain

Table 4: Computational domain size

X min	-0.249m
X max	0.325m
Y min	0.125m
Y max	0.362m
Z min	0.367m
Z max	1.115m

2.2 Physical Features

Gravitational effects: On

Flow type: Laminar and turbulent

Cavitation: On

Table 5: Gravitational settings

X component	0m/s ²
Y component	-9.81m/s ²
Z component	0m/s ²

Default wall conditions: Adiabatic wall

Table 6: Ambient conditions

Thermodynamic parameters	Static Pressure: 101325.00Pa Temperature: 293.20K
Velocity parameters	Velocity vector Velocity in X direction: -1.000m/s Velocity in Y direction: 0m/s Velocity in Z direction: 0m/s

2.3 Material Settings

Fluids - Water

Rotating regions

Table 7: Rotating regions

Component	SHAFT@RUNNER.SLDPRT
Angular velocity	30.000rad/s

2.4 Calculation Mesh

Table 8: Basic Mesh Dimensions

Number of cells in X	16
Number of cells in Y	7
Number of cells in Z	22

Table 9: Number of Cells

Cells	20130
Fluid cells	13244
Solid cells	6886
Irregular cells	0
Trimmed cells	0

3.0 Results and Discussion

Power from water, $P_{\text{input}} = 3678.75\text{W}$

Input power =	γQH	3678.75
	$\gamma = \rho g$	9810
	H	1
	$Q = AV$	
	$V = 1$	1
	$A = 0.75 * 0.5$	0.375

Table 10: Results of the five runners simulated

No. of blades	Torque	angular speed	Output power	Efficiency
44	110.2	30	3306	89.90%
37	110.2	30	3306	89.90%
30	111	30	3330	90.50%
23	40.6	30	1218	33.10%
16	3.7	30	111	3.00%

Table 11: Gauss – Newton estimates for three coefficients Theta 1, 2 and 3 at each iteration

Iteration	SSE	Theta1	Theta2	Theta3
0	86698.5	50.0000	1.0000	0.000000
1	4109.8	87.4373	1.0000	0.051109
2	2597.2	94.9457	44.2473	0.883494
3	2653.0	94.8584	7.9958	0.006543
4	2641.5	93.1765	6.8640	0.009714
5	2550.5	91.8352	6.7442	0.016522
6	2509.8	87.7526	25.9728	0.134190
7	1460.2	89.6147	28.2125	0.072437
8	149.7	95.3395	43.6131	0.065948
9	146.3	95.2714	44.1407	0.070796
10	146.0	95.3253	43.7655	0.069056
11	146.0	95.3081	43.9139	0.069768
12	146.0	95.3154	43.8549	0.069485
13	146.0	95.3126	43.8786	0.069599
14	146.0	95.3137	43.8692	0.069554
15	146.0	95.3133	43.8730	0.069572
16	146.0	95.3135	43.8714	0.069564
17	146.0	95.3134	43.8720	0.069567
18	146.0	95.3134	43.8718	0.069566
19	146.0	95.3134	43.8719	0.069567
20	146.0	95.3134	43.8719	0.069566

21	146.0	95.3134	43.8719	0.069567
22	146.0	95.3134	43.8719	0.069567
23	146.0	95.3134	43.8719	0.069567

The results from the simulation of an external fluid flow, experiencing both laminar and turbulent flow and subject to cavitation of the turbines with a different number of blades are shown in figures 3 to 19 in the order of:

- Cut plots of velocity contours (Figure 3, 4, 5, 6, and 7)
- Cut plots of total pressure distribution contours (Figure 8, 9, 10, 11, and 12)
- Flow trajectory of velocity (Figure 13, 14, 15, 16, 17, 18, and 19)

The figures display the superficial velocity of the streamlines, the visual flow trajectory of the flow, and the pressure distribution in the runner blades. Since the flow is an external flow with the runner floating on the water, only a portion of the runner is in contact with the water. The influence of the number of blades on the velocity, pressure, and trajectory is visible. The runner blades provide both the entry and exit of the fluid through the runner. The velocity cut plots for 16, 23, 30, 37, and 44 in figures 3, 4, 5, 6, and 7, respectively, reveal that when the number of blades increases, water escapes from the runner increases as a result of reduced exit area and increased exit angle resulting to an increase in superficial velocity at the exit stage of the runner. However, at the entry point, the flow will be more obstructed as the number of the blades increases, increasing the superficial velocity at the entry stage of the runner. At the middle of the runner, when the blades increase from 16 to 44 except for 30 blades, there is splashing of water from the inner side of the runner towards the empty space of the runner shaft. Upon the loss of water momentum, the splashes fall to the runner's lower part and eventually join the downstream. These splashes have a relatively low velocity compared to the flow velocity. However, for a 30 blade runner, the velocity is almost uniform, with less splashing at the runner's center. The tremendous splashing and loss of momentum in 16 and 23 blades reduce efficiency and power output. Nevertheless, in 37 and 44 blades, the entry and exits points acts as an opening that allows water to freely move, thereby not allowing optimum conversion of the kinetic energy of water to mechanical energy of the runner. This, in turn, reduced the turbine efficiency and power output.

Looking at the flow trajectory for 16, 23, 30, 37, and 44 in figures 13, 14, 15, 16, 17, 18, and 19, respectively, it is clear that as the number of blades increases, the streamlines form a high-velocity backflow region at the center and near the exit of the runner. The magnitude of these backflows is reduced by the increased number of blades but then recurs for blades above 30. Also, the streamlines somehow separate at the exit stage when 16, 23, 37, and 44 blades are employed. This can cause power losses and a reduction in turbine efficiency.

The runner's total pressure distribution is depicted in figures 8, 9, 10, 11, and 12 for both contours and flow trajectory. The regions with atmospheric pressure represent areas without liquid flow which do not hold water; instead, they indicate the absence of interaction between the blades and water. This leads to a drop in output power and consequently low efficiency. In low blade numbers of 16 and 23, the broad blade spacing

allows water to exit at relatively high pressure, thereby underutilizing the available potential energy of water and consequently power output. The close spacing in high blade number provides almost a horizontal gradient between the inlet and exit points, thereby equally creating zones of no interaction between water and blade. This gives rise to wastage of potential energy of water and subsequently low power output. However, when 30 blade runner was simulated, there were no regions of atmospheric pressure within the runner, and this gives the optimum energy conversion.

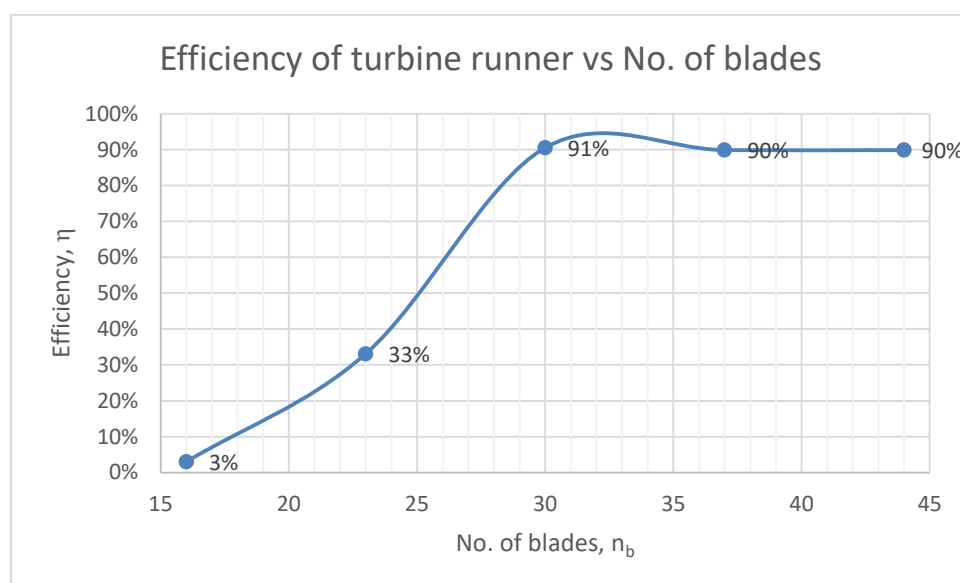


Figure 9: Efficiency of turbine runner vs. No. of blade

The efficiency graph in Figure 19 shows a direct relationship between the number of blades and the efficiency for blade numbers from 16 to 30, whereby the efficiency increased with the number of blades. This is attributed to the above phenomenon of the runner's velocity and total pressure distributions. It was observed that much energy was tapped as the number of the blades increased due to reduction in flow streamline separation and reverse circulation and increase in cross-flow between the inlet and outlet of the runner. However, increasing the blades from 30 to 44 reduced the efficiency for both 37 and 44 blades. This can be attributed to streamline coalitions that result in reverse flow leading to increased flow velocity at the exit of the blade and thus a reduction in flow area. Also, the increase in the momentum of the runner due to increase in weight can cause reverse velocity that can lead to loss of power output.

Therefore, the most appropriate and optimum number of runner blades in low head and velocity river flows is 30, with an efficiency of 91%. Thus, 30 blades should be considered for very low heads on external flows. This concurs with the findings of Desai and Aziz (Desai and Aziz, 1994), who found that the optimum number of blades was 30 and that the efficiency of cross-flow turbine increased with the number of blades from 15 to 30 blades.

From Gauss – Newton Algorithm in Table 8, the iteration results for the appropriate coefficients that suit a cross-flow efficiency trends can be substituted in the asymptotic regression in equation 1 and the estimated as shown in equation 2.

$$\text{Response} = \vartheta_1 - \vartheta_2 * e^{(-\vartheta_3 * \text{Predictor})} \dots\dots\dots \text{Equation 5}$$

Parameter Estimates

Parameter	Estimate	SE Estimate	95% CI
ϑ_1	95.3134	0.32368	(94.6762, 95.9545)
ϑ_2	43.8719	1.79288	(40.4672, 47.3531)
ϑ_3	0.0696	0.00495	(0.0616, 0.0786)

$$\% \text{ Efficiency} = 95.3134 - 43.8719 e^{(-0.0695665 * N_b)} \dots\dots \text{Equation 6}$$

Where N_b is the number of blades.

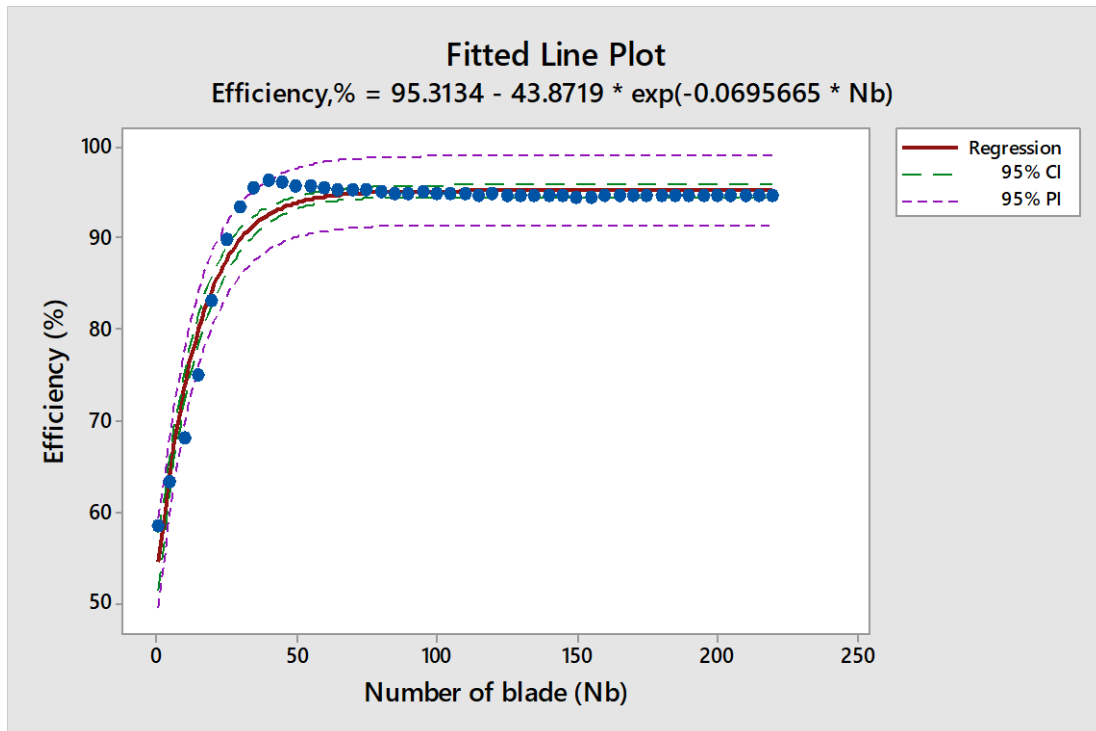


Figure 10: Asymptotic non-linear regression plot for efficiency and N_b at 95% CI

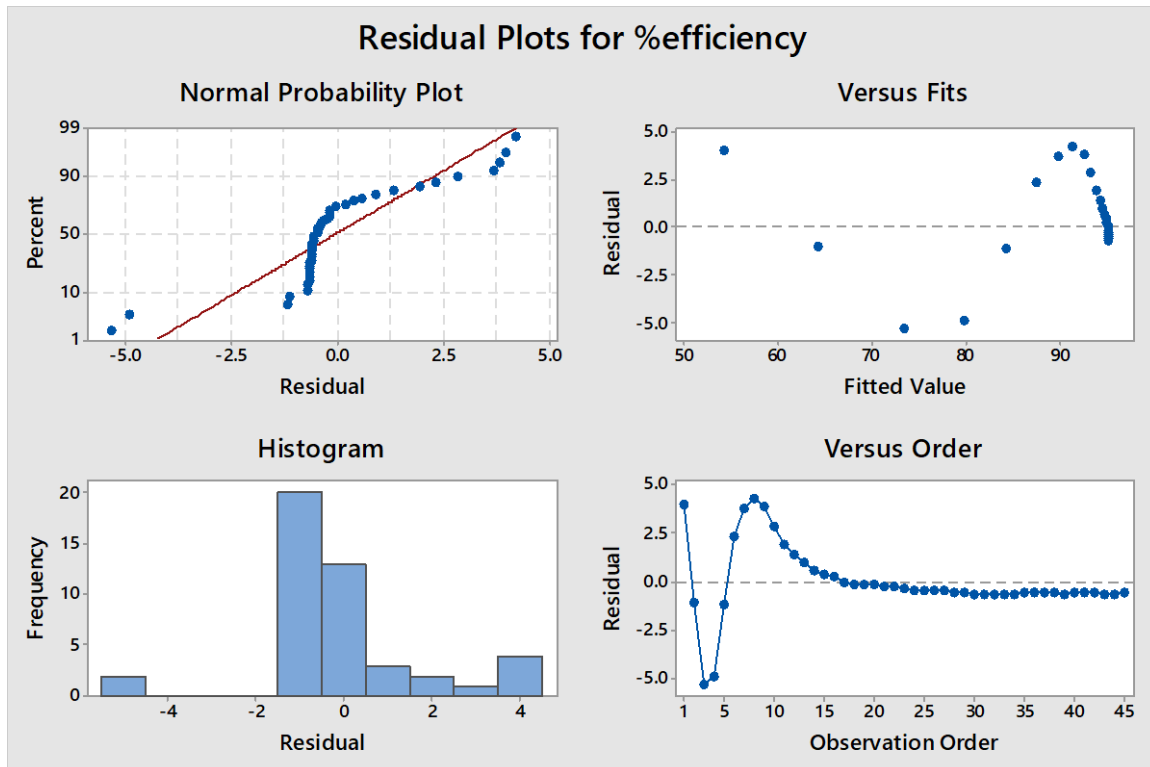


Figure 11: Residual plot for % efficiency

In Figure 20, the plot of the % efficiency data indicates that the specified rational polynomial is a good fit for the data. The points are fairly close to the curve and follow the curve without any systematic departures from it. Hence, the formulae for estimating the number of blades in a low head and velocity flows can be designed by this fitted line equation.

In Figure 21, the normal probability plot indicates that % efficiency increases with the increase in the number of blades until the optimum threshold is reached when the efficiency stagnates. The histogram indicates a normal distribution of the data, while the plot of residue versus fits and order indicates that the data is distributed around the zero residual. Hence no evidence of non-normality, skewness, outliers or unidentified variables exists.

Equation 2 gives the proposed fundamental theory for future design calculation and selecting the appropriate number of blades for a low head and velocity cross-flow turbine design efficiency.

4.0 Conclusion

The efficiency of the cross-flow turbines can be optimized by adopting the optimum number of runner blades as 30 blades. Selecting too few runner blades, the flow streamlines separate at the center of the runner, causing loss of power. While selecting too many blades, streamline coalitions that result in reverse flow lead to increased flow velocity at the exit of the blade. Thus, reduction in flow area reduces power output. This is supplemented by the increase in weight. Thus 30 blades are the optimum number of blades for cross-flow turbines. However, the proposed equation can be adopted as a

design formula for future selection of the number of blades for a low head and low-velocity cross-flow turbine suitable for run-off river installations.

It is also evident that finite elements' CFD is the optimum approach for adoption in the simulation and optimization of mechanical and industrial systems. It has added value to the pool of knowledge vital for engineers and designers in this respect.

Figures 3 to 19

a. Cut plots of velocity contours

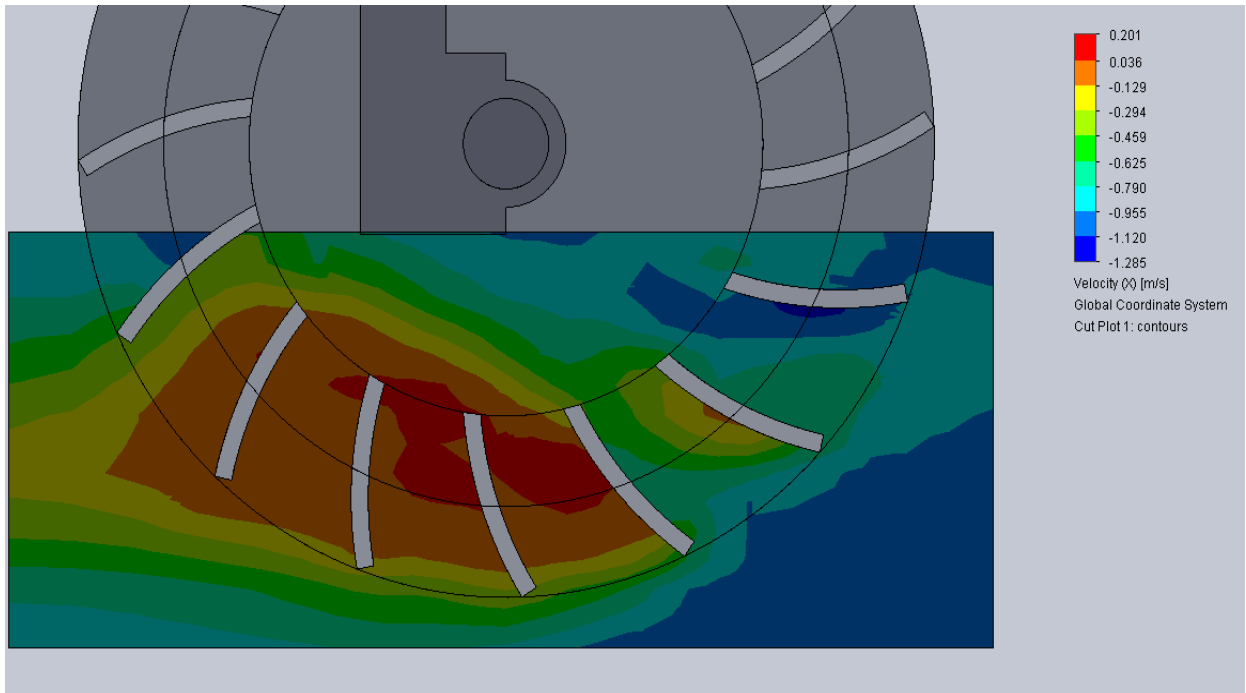


Figure 12: Cut plot of velocity contour for 16 blade runner

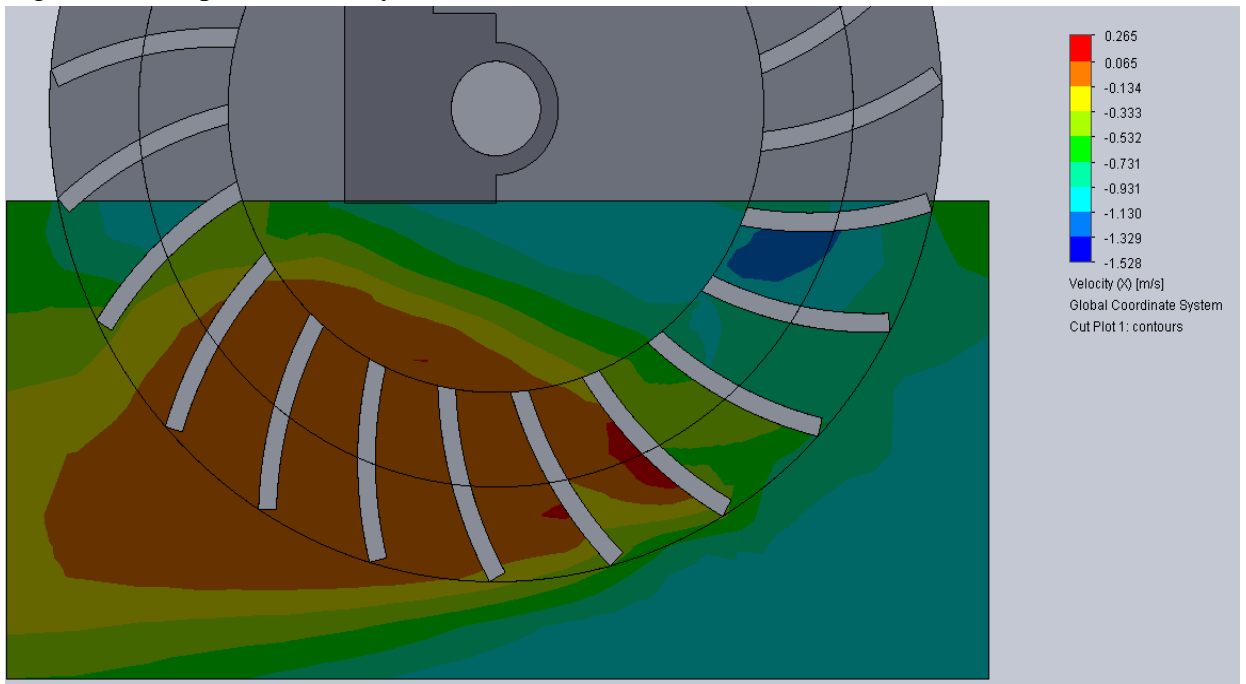


Figure 13: Cut plot of velocity contour for 23 blade runner

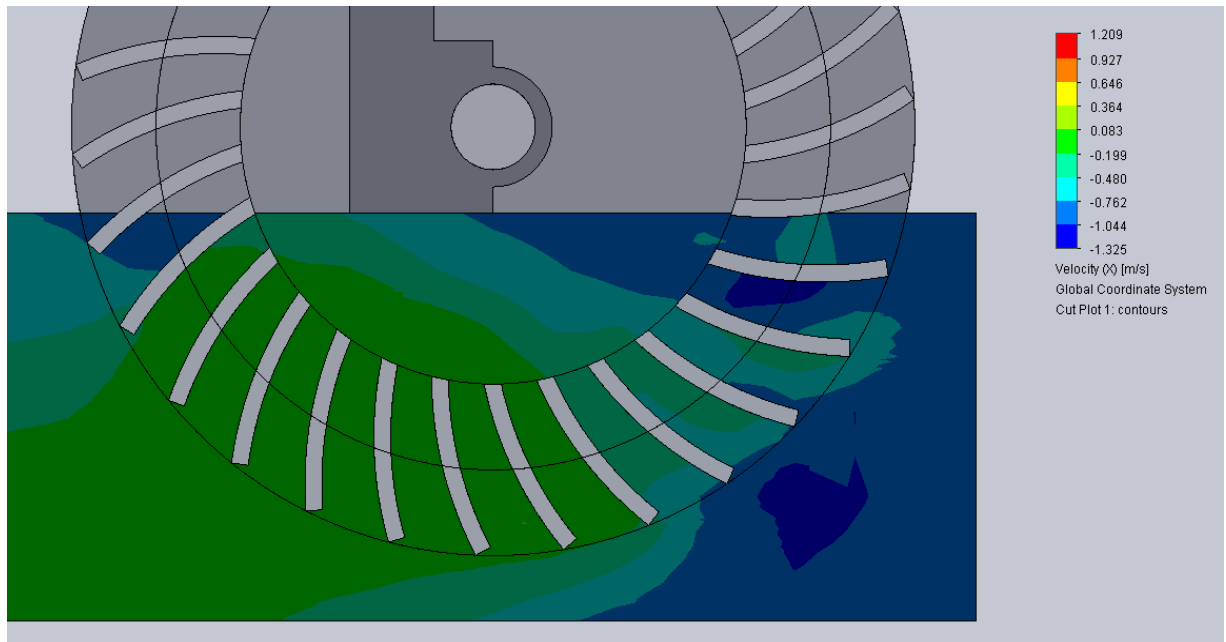


Figure 14: Cut plot of velocity contour for 30 blade runner

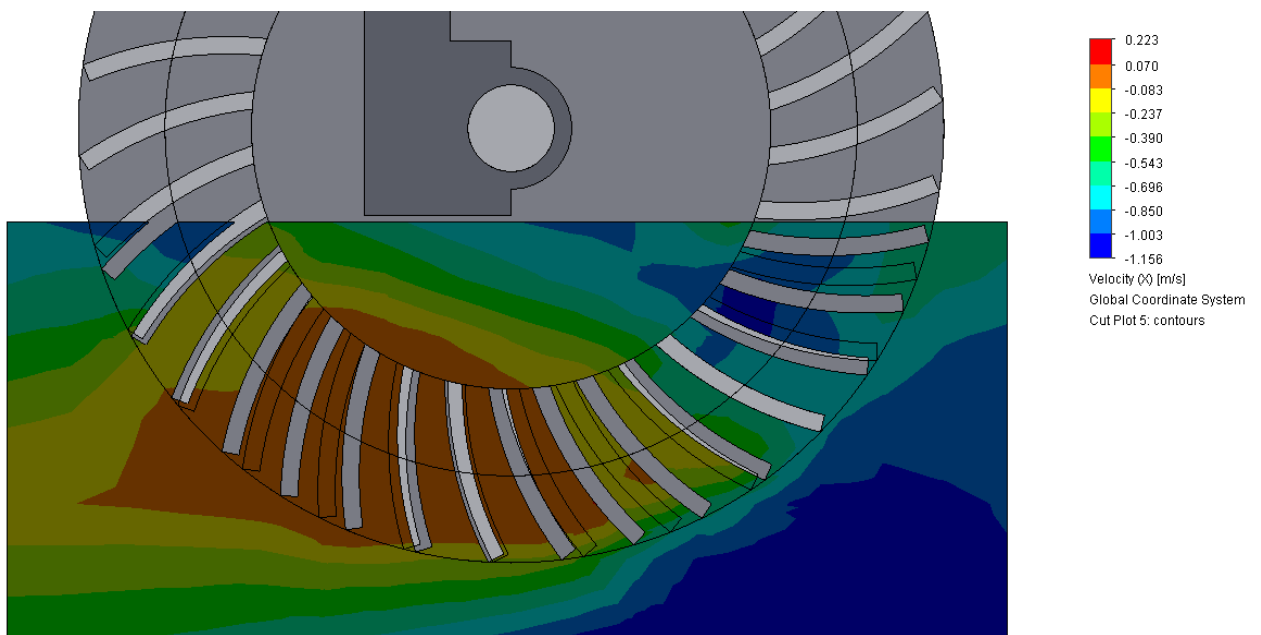


Figure 15: Cut plot of velocity contour for 37 blade runner

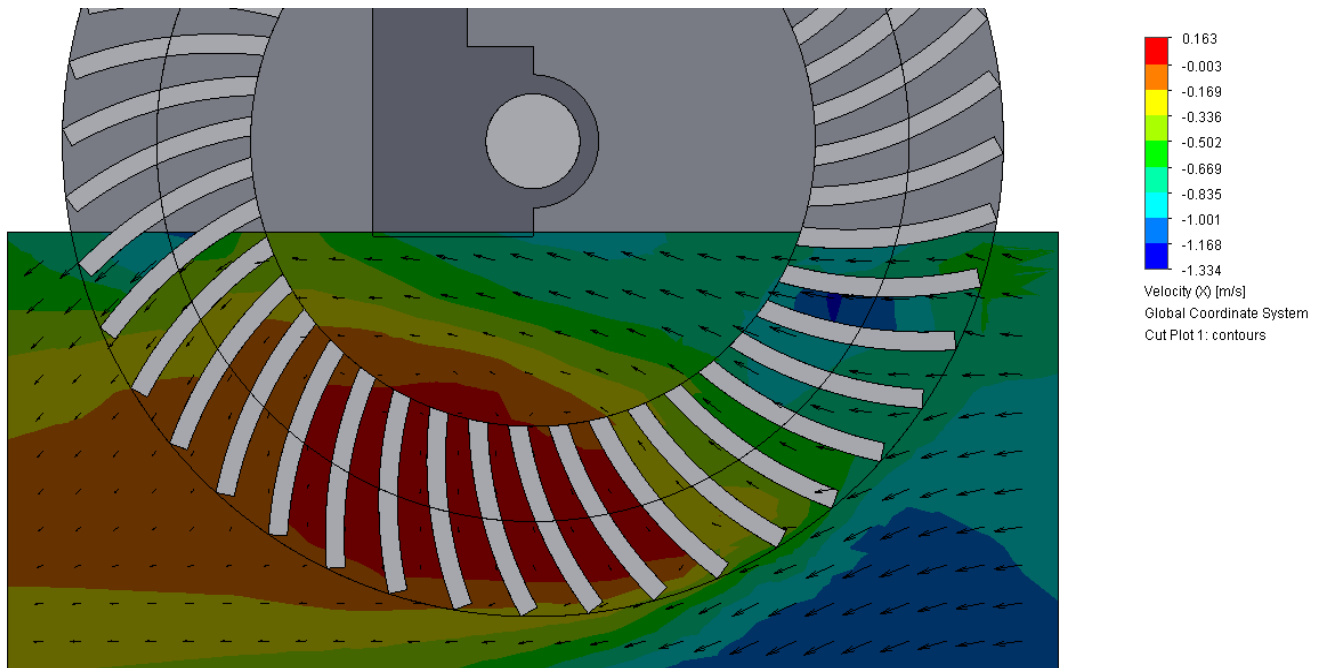


Figure 16: Cut plot of velocity contour for 44 blade runner

b. Cut plots of total pressure distribution contours

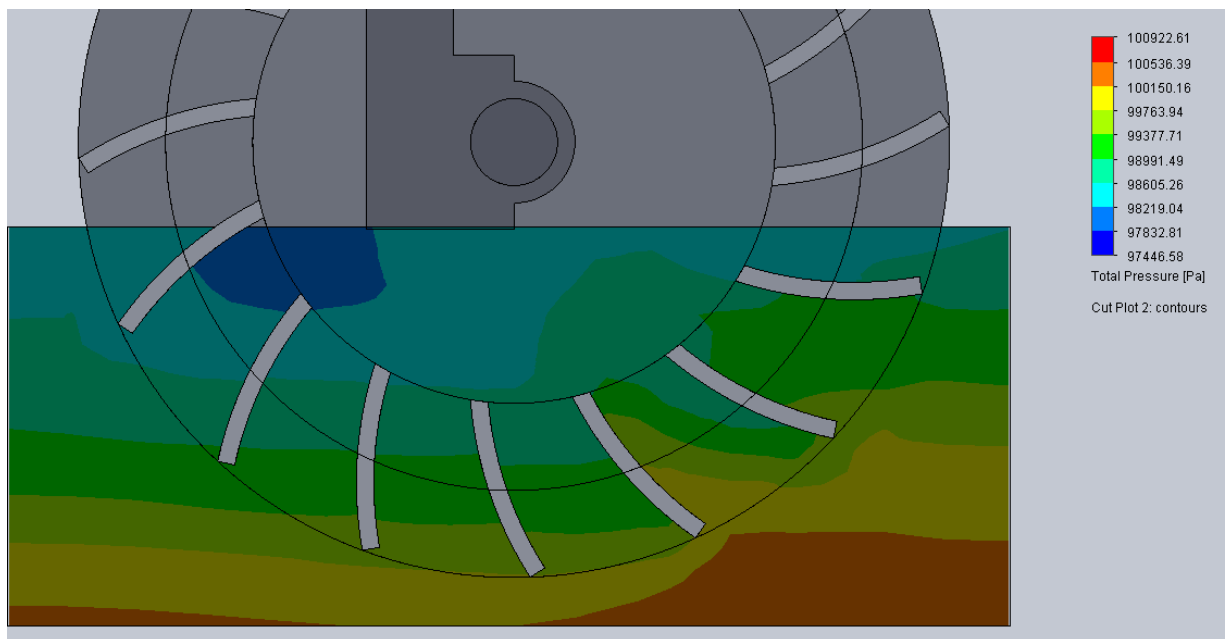


Figure 17: Cut plot of total pressure distribution contour for 16 blade runner

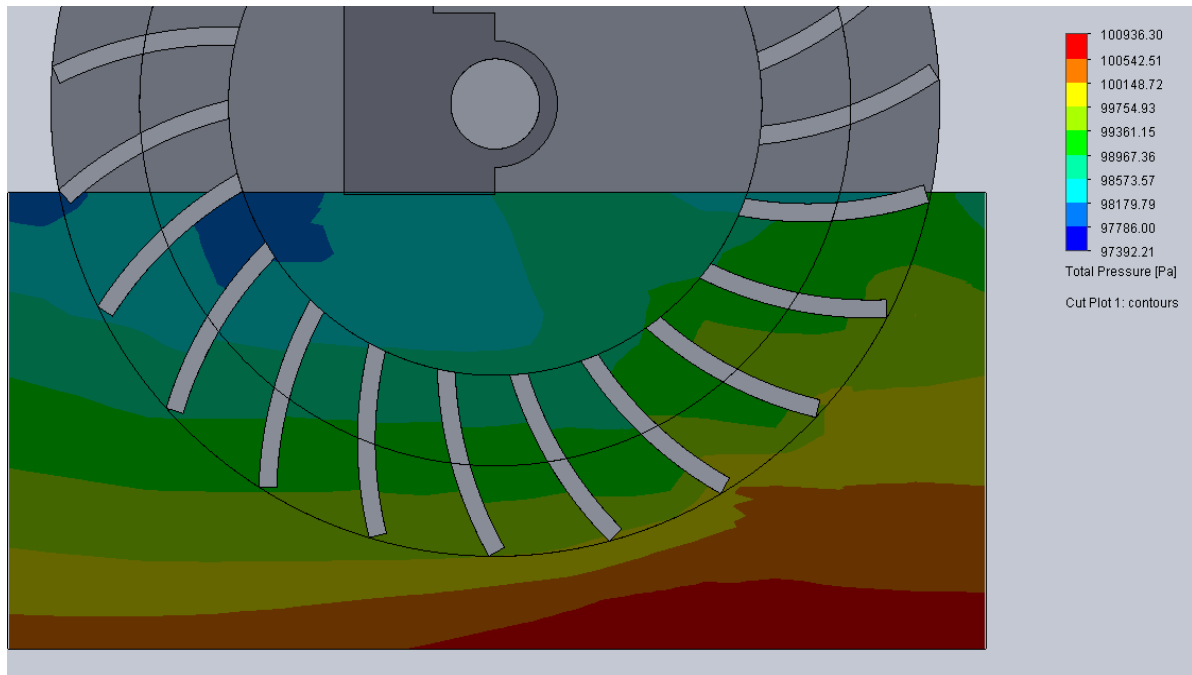


Figure 18: Cut plot of total pressure distribution contour for 23 blade runner

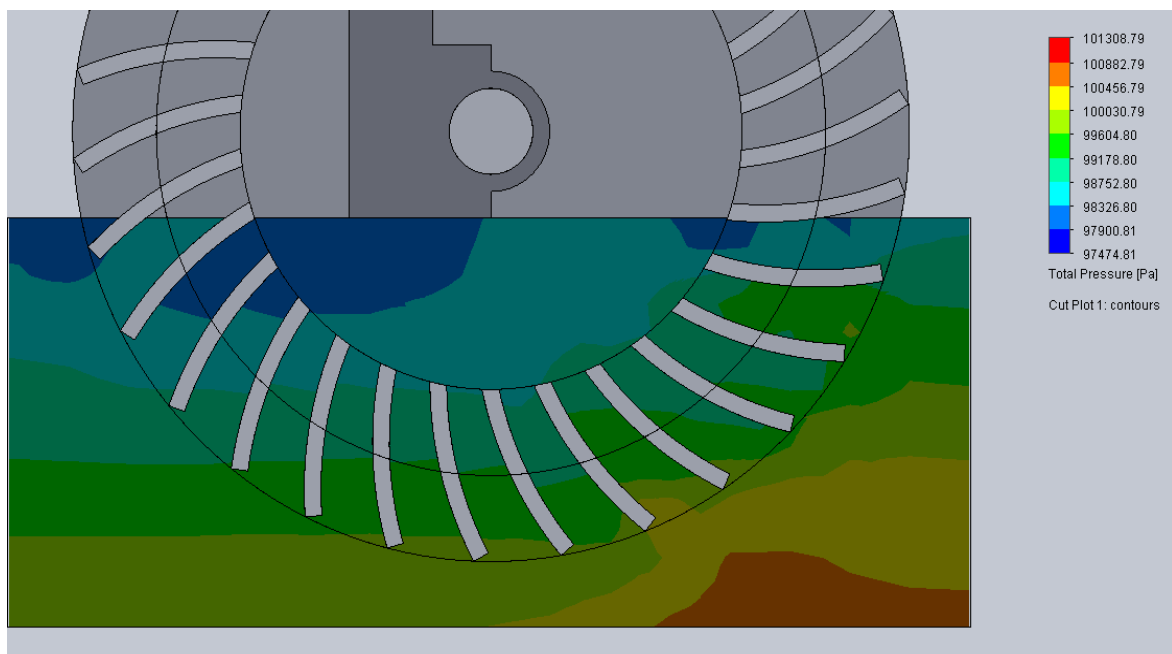


Figure 19: Cut plot of total pressure distribution contour for 30 blade runner

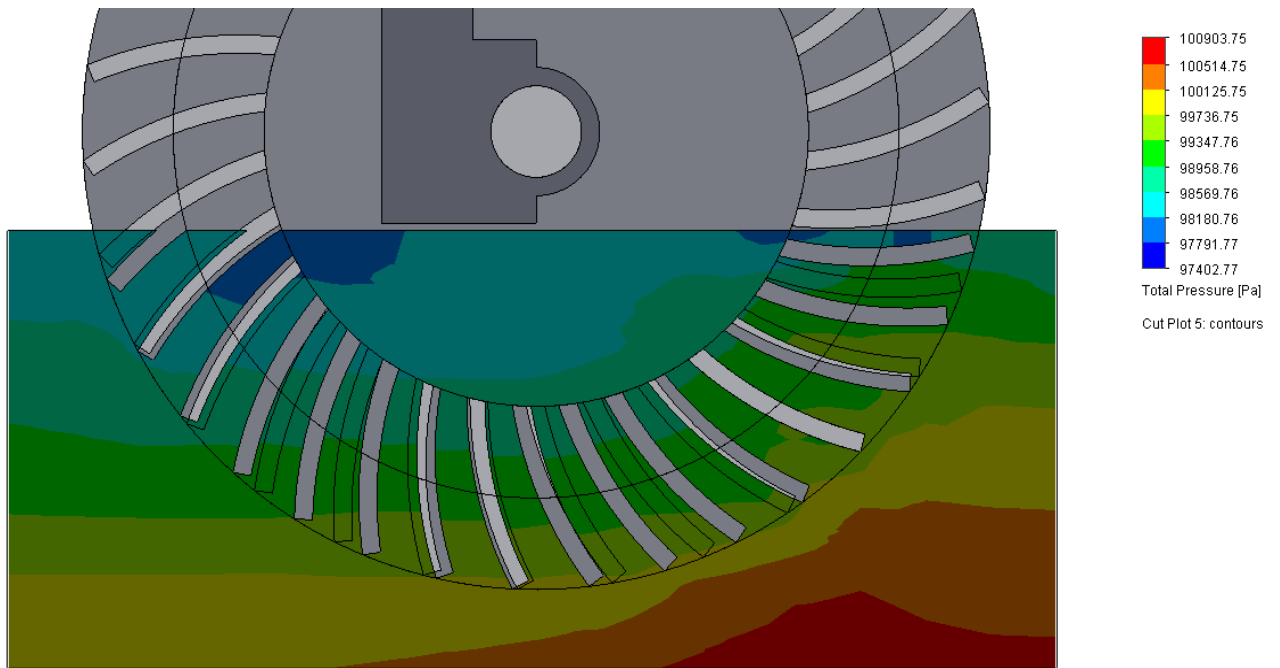


Figure 20: Cut plot of pressure distribution contour for 37 blade runner

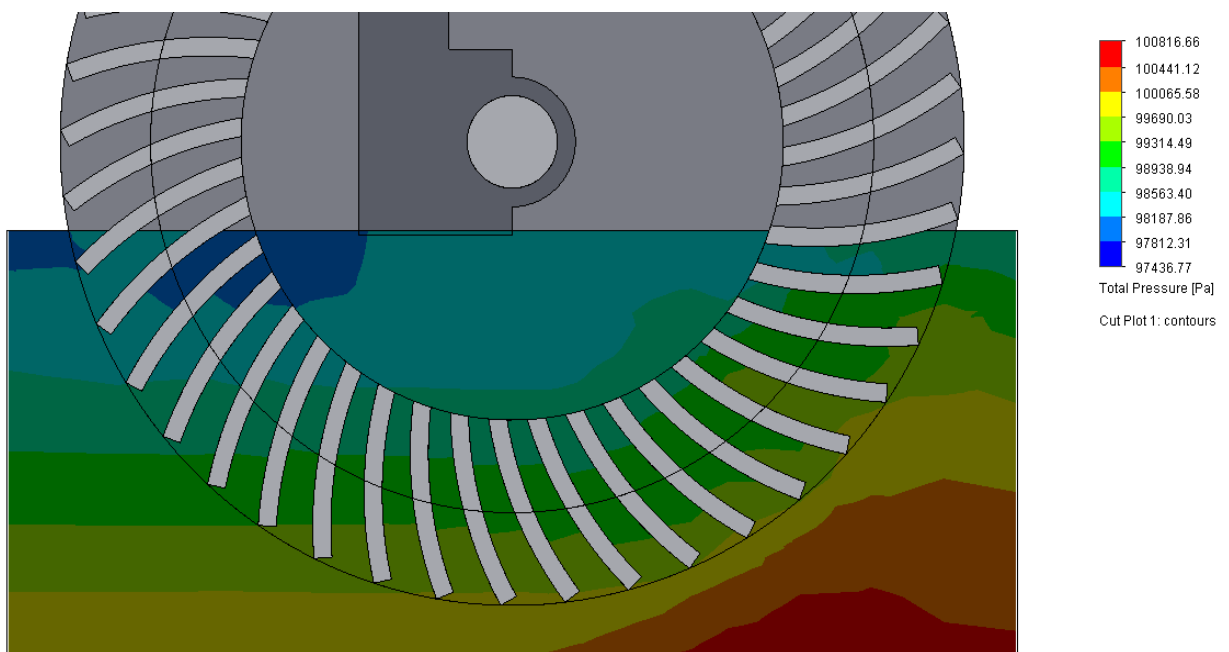


Figure 21: Cut plot of pressure distribution contour for 44 blade runner
c. Flow trajectory of velocity

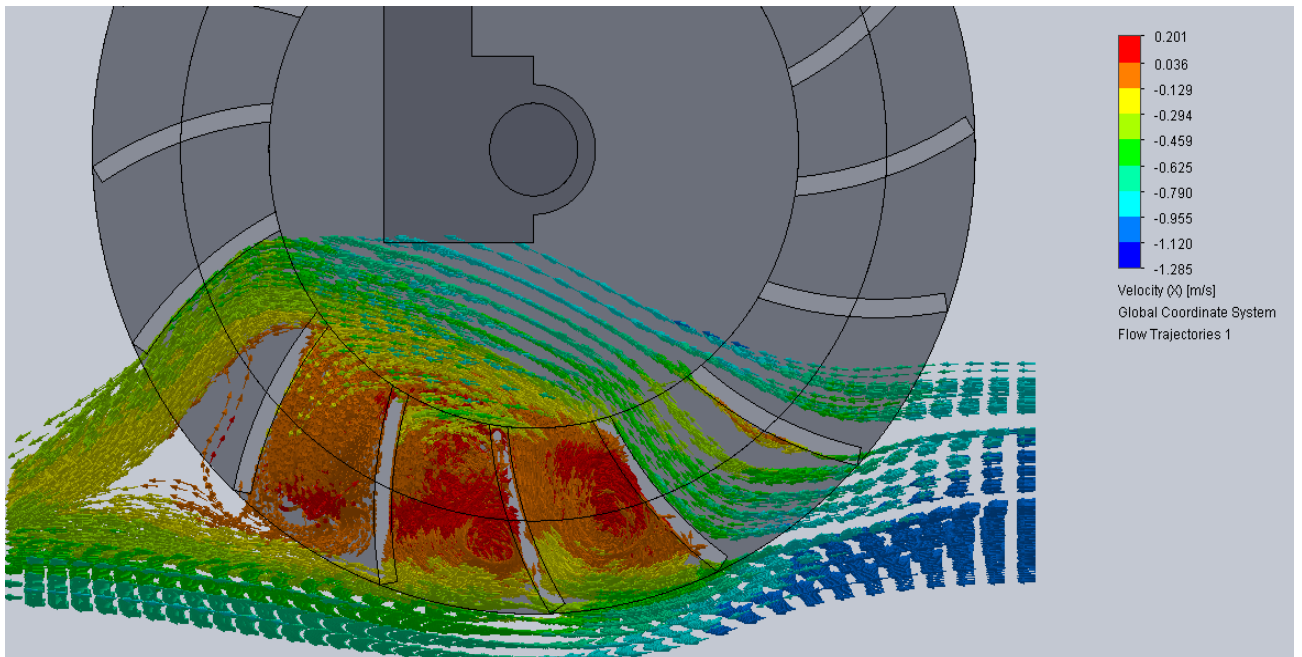


Figure 22: Flow trajectory of velocity for 16 blade runner

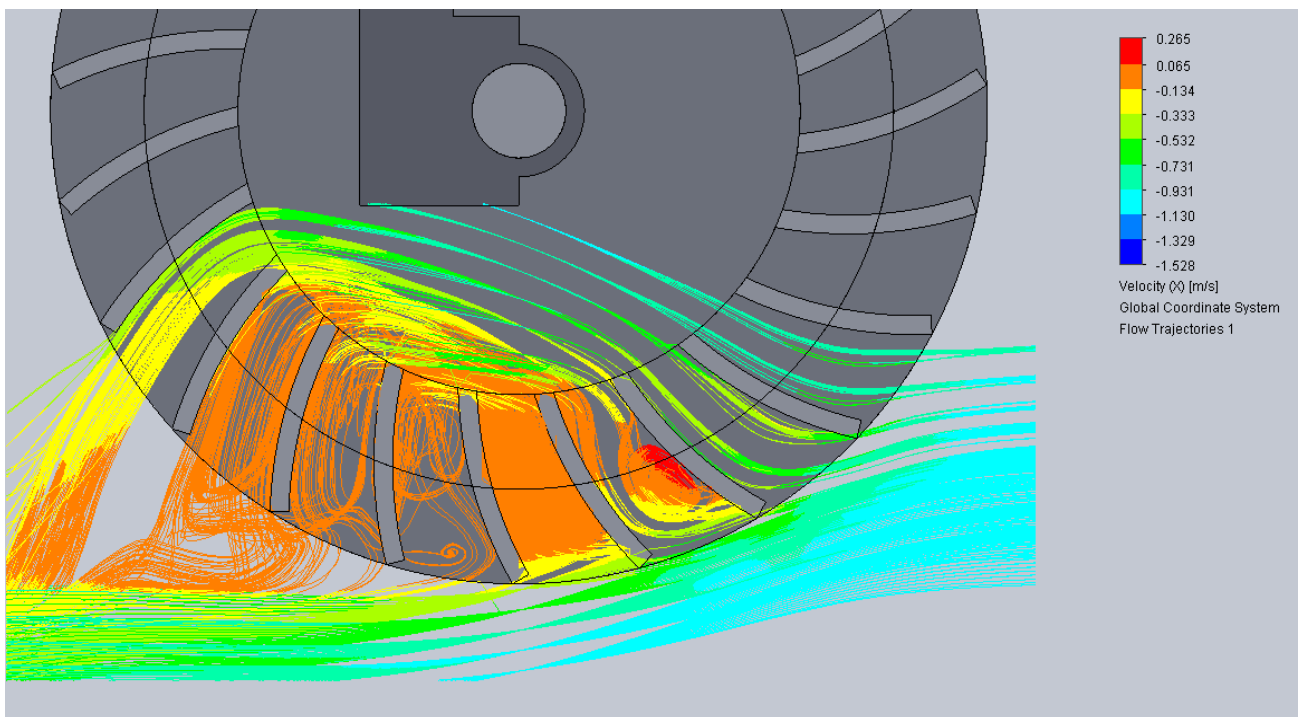


Figure 23: Flow trajectory of velocity for 23 blade runner

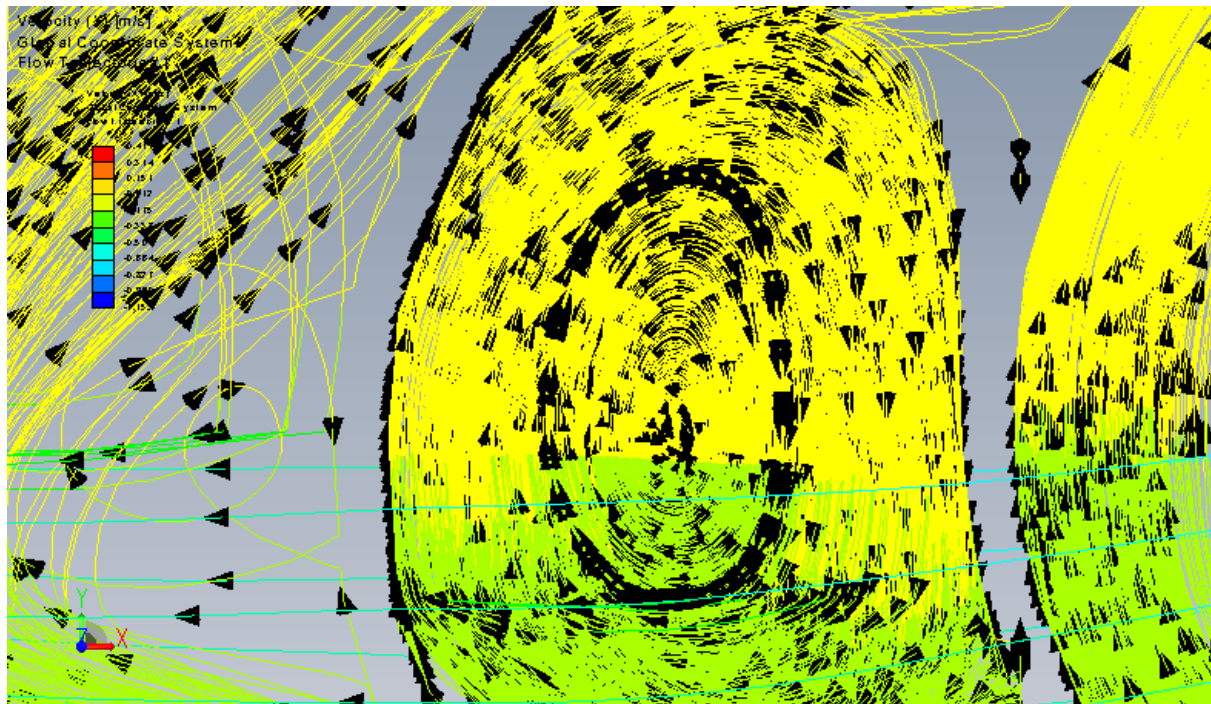


Figure 24: Zoomed flow trajectory of velocity for 23 blade runner

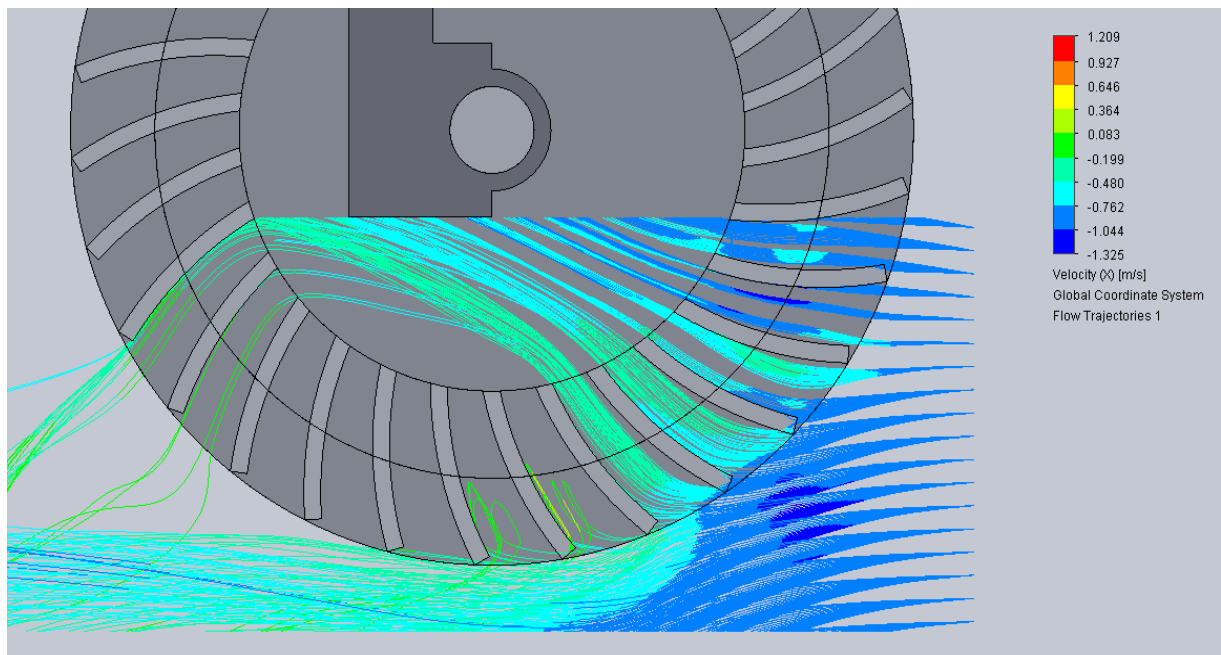


Figure 25: Flow trajectory of velocity for 30 blade runner

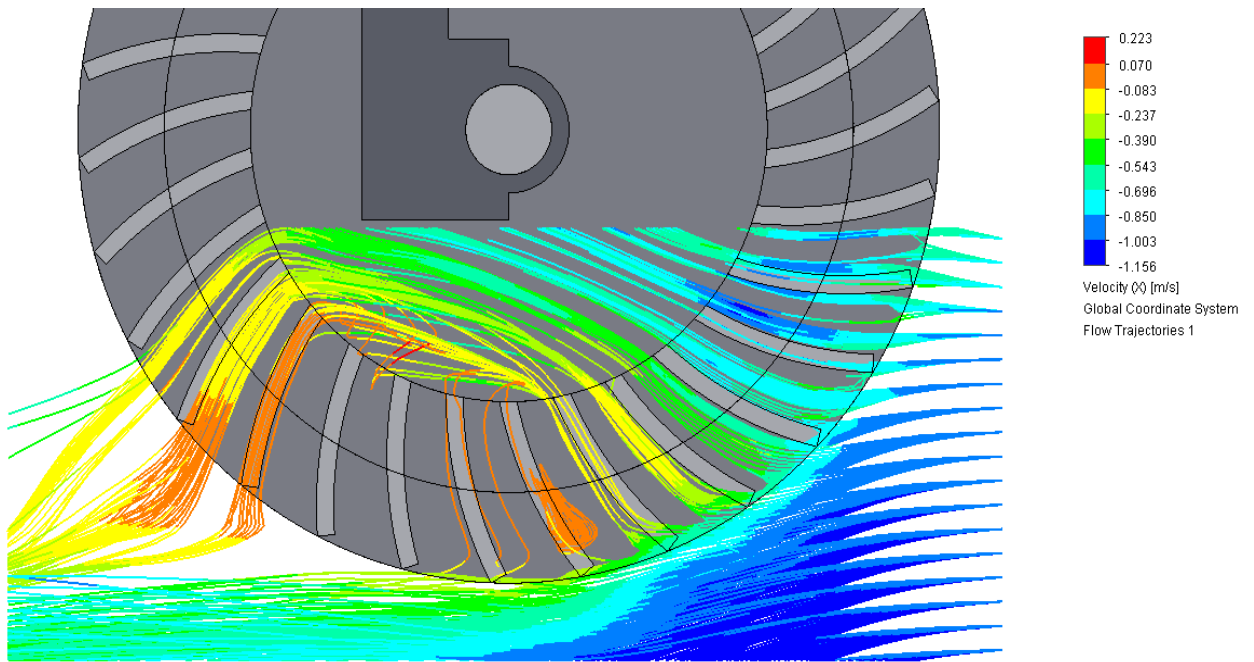


Figure 26: Flow trajectory of velocity for 37 blade runner

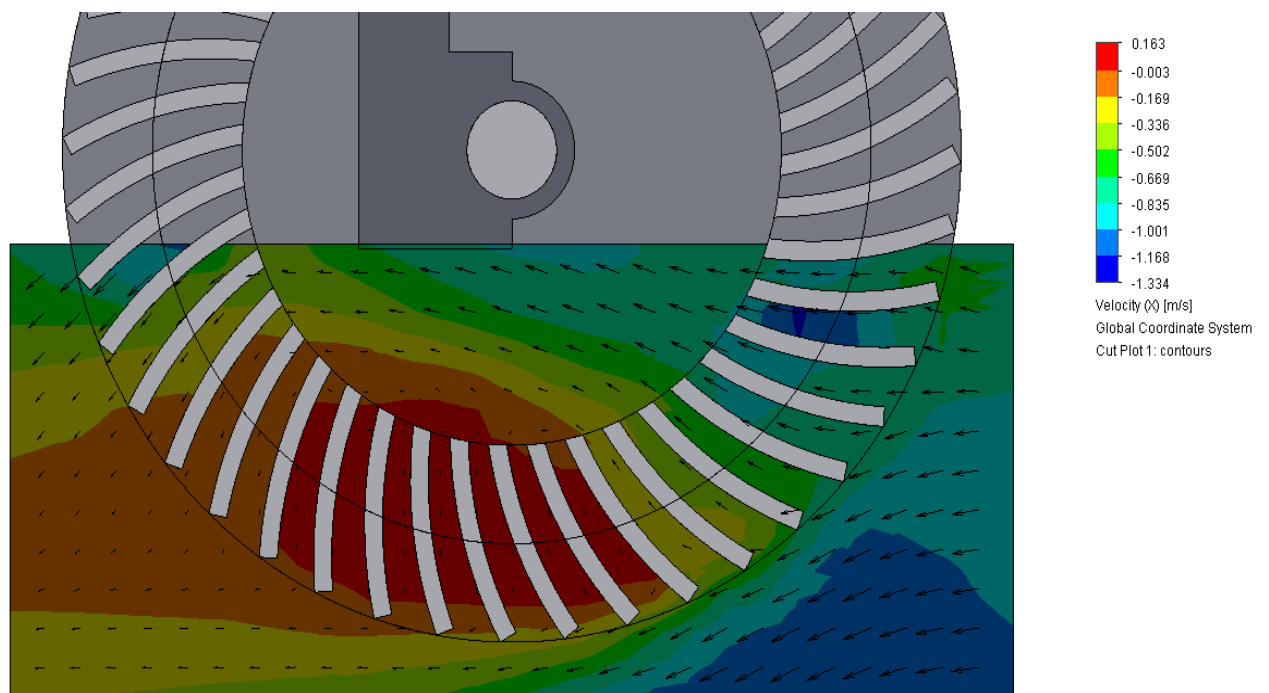


Figure 27: Cut plot of velocity contour for 44 blade runner

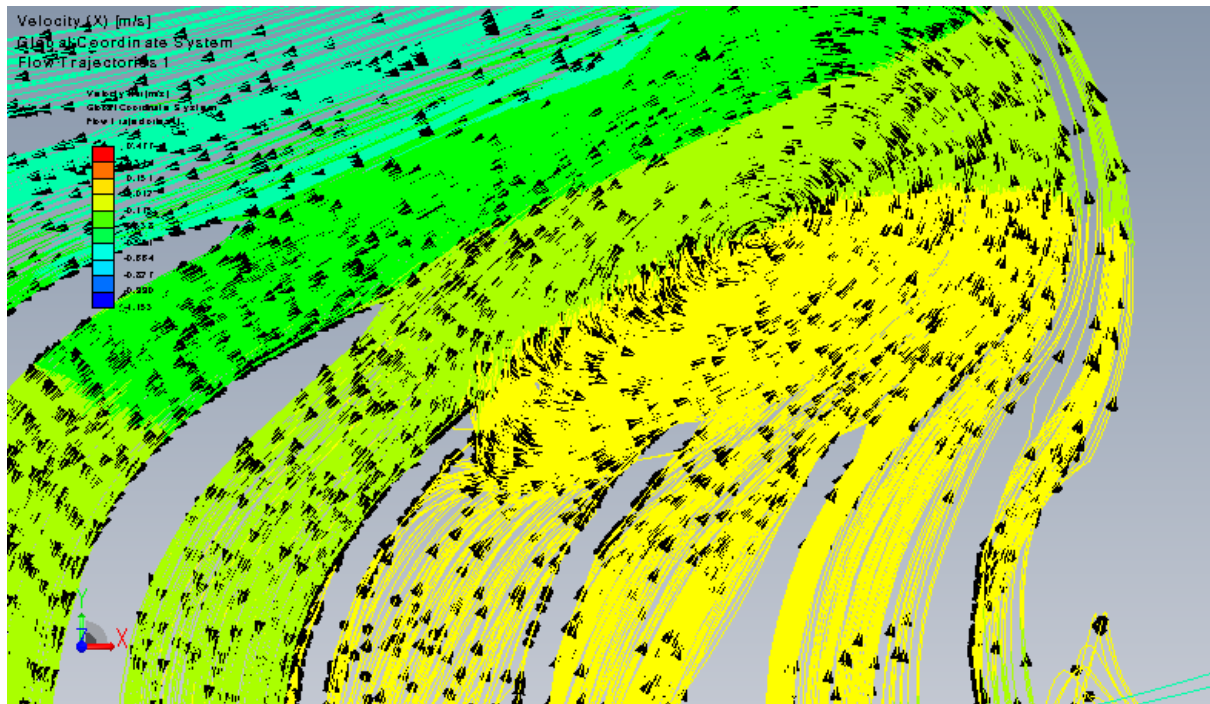


Figure 28: Zoomed flow trajectory of velocity distribution for 44 blade runner

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Design, Fabrication, and Testing of an Experimental 3-D programmable Milling Machine for training at Masinde Muliro University of Science and Technology

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Abstract

Most milling operations across the globe and specifically at MMUST's Mechanical Engineering workshop are executed using 2-D milling operations, which results in various shortcomings. With the application of the 2-D milling operations, there is high inefficiency resulting from inaccurate machining. Moreover, milling operations are costly and time-consuming due to the constant need to control the operations. Additionally, the high cost of purchasing milling machines makes practical demonstrations on the principle of operation difficult, especially for students in universities and technical colleges. This project aims to close this gap by developing a low-cost, efficient, and programmable 3-D milling machine for educational and small-scale operations. The project will also be fundamental in helping the Kenyan government push industrialization. To achieve the project's objective, a programmable 3-D milling machine prototype was designed and fabricated, overcoming the challenges experienced in the current milling operations. After Fabrication, the prototype was tested, establishing a reduction in milling time, increased efficiency, increased accuracy, and reduced complexity of use.

Keywords: Milling, Manufacturing, Learning Tool, CAD/CAM, Programming

5.0 Introduction

The importance of manufacturing and having skilled manufacturers in the United States industry has been apparent since the industrial revolution in the 1800s. The economic change that occurred when production went from skilled craftsmen to machines and factories has helped make the U.S. the superpower nation it is today. Since the modern industrial revolution took place in 1973, all areas of the industry, from technologies, politics, and the economy, have all been influenced and changed dramatically (Verma, 2018). The manufacturing industry's skill is to create a quality part that meets the consumer's specifications for the least amount of money. In developing countries like Kenya and other African nations, poor development can be attributed to inadequate manufacturing innovations. With inadequate manufacturing, the continent relies heavily on importing parts, thus increasing their costs.

The progression and advances in manufacturing continue to decrease the cost of production and further decrease the overall cost of goods which, in turn, affects the national economy. Today the U.S. faces the difficult issue of overseas outsourcing

manufacturing jobs to countries like China, Thailand, and Japan to save on production costs. Although this outsourcing may be helpful in the short term and temporarily boost bottom-line profit, the recent disaster in Japan shows us how dangerous outside reliance can be. United States companies are constantly looking for skilled manufacturing engineers and machine specialists to increase their productivity and lower machining costs (Smid, 2003).

Globally, more than 100 million people rely on manufacturing jobs. In Kenya, over 1000 companies, hundreds of start-ups, and millions of people in the Juakali industry are heavily reliant on manufacturing. With such high demands for manufacturing enhancement, it is fundamental for a revolution in the available machines. One such change can be attained through new innovations like the programmable 3-D milling machine.

With the right experience and skill in manufacturing and machining, one has the opportunity to make more money, on average, than jobs in other fields of the economy, even without a college degree. Machine experience and manufacturing understanding can be detrimental to getting and sustaining an income without a degree and significantly increasing the starting income. In addition to the economic contributions of the manufacturing industry, it is also a vital contributor to national matters. Decreasing Kenya's dependency on imported energy like oil and reducing greenhouse gas are both directly related to the new materials developed by the vibrant manufacturing industry.

Milling is the process of cutting and shaping materials into the desired part. Milling operations are performed on milling machines, gear-cutting machines, and machining centers. Milling machines are complex devices that perform several operations. The actual shaping of the part is done with a cutting tool attached to a spindle, delivering rotational forces. Milling machines have either horizontally or vertically aligned spindles. The machines are either manually operated or Computer Numerically Controlled (CNC) (Smid, 2003). It is far more effective to use a CNC machine in complex operations. Milling operations are usually classified as face milling, end 24 millings, and slotting. Important concepts in milling are conventional milling (or up milling) and down milling.

In conventional milling, the cutting force runs opposite to the feed direction. The constant pressure can be maintained, so backlash has no significant effect on the cutting process. One of the negatives of conventional milling is that the cutter sometimes rubs against the workpiece. This can considerably reduce both tool life and cutting accuracy. Many modern milling machines have anti-backlashing systems in order to counteract this problem. Conventional milling has a significant advantage when machining materials with high ductility and work hardening properties. Milling operations using manually operated mechanisms are highly inefficient due to the errors encountered during the feeding and placement of workpiece materials. The current paradigm also makes milling costly and time-consuming as operators have to control most processes manually. The operations are also hazardous as operators are constantly changing workpiece positions

conform to the cutter axis. The machined components have low accuracy levels due to the errors encountered during feeding and positioning operations (Balic, 2006).

The high costs of purchasing milling machines have also led to detrimental implications on the industrialization bid for low-income countries like Kenya. Essentially, the available milling machines are expensive to purchase and require skill to operate. Technicians have to pass through concrete training to understand the basic operations of such machines. It is difficult for the Kenyan government to achieve its industrialization goal with the current situation. The available CNC machines are bulk and expensive, making it difficult for non-skilled Kenyans to access them. Simple and cheaper milling machines will make it easier for Juakali and other artisan workers to produce their components, thus improving livelihoods in the country. With this project, most people will afford machining due to creating a simple to use design. The project will significantly supplement the government's industrialization efforts by making machining more convenient (Bang et al., 2005).

Machining is a vital manufacturing process that is used in a wide range of applications. From aerospace applications to manufacturing energy systems and medical robots, we see a major reliance on machining. Mills are machines that are similar in appearance and style to the drill press but differ in function and use. In addition to cutting surfaces on the bottom of a mill bit, the sides are utilized as well. This dramatically expands the functionality of milling and greatly reduces the need for extremely large inventories consisting of cutting tools that may rarely be used. Modern mills employ various cutting tools, such as the face, end, and ball-mills. Utilizing tools such as these allow for operations slot cutting, planing, drilling, contouring, and die-sinking (though more exist). This broad range of use allows a skilled machinist to tackle many of the machining tasks commonly encountered. However, mills have not always been this versatile and may have begun with rotary filing (Barret, 2013).

Nowadays, most users of personal machines, or even industrial applications, have a specific machine(s) for prototyping and for machining. Nevertheless, the steep increase in demand for machines for personal use and the fact that those machines provide either one of the two processes, i.e., prototyping and milling, there is a niche market for a machine that can perform both processes. Many consumers, especially in industry, possess manufacturing processes on entirely different machines, and few attempt to retrofit one for the other process. The CNC milling presented here is crucial for personal manufacturing. With the popularity of people making their own parts at home and the ease of buying components and machines in today's world, even those without experience in these processes can jump in and learn about personal manufacturing. Important aspects considered were milling machines and the crucial acquisition of this component in a form that would allow both processes to work. The machine will be an essential learning tool for classrooms and a resource to expose students to manufacturing technologies. It also serves as a level of comparison to available products in the market. Lastly, the machine

fits with personal manufacturing by having a smaller footprint, easy operation, and interchangeability of the processes (Kopac and Kampus, 2005).

Milling machines are very versatile in their use. They are usually used to machine flat surfaces, but they can also produce irregular surfaces. They are also used to drill, bore, cut gears, and produce slots. The primary function of milling machines is to produce flat surfaces in any orientation as well as surfaces of revolution, helical surfaces, and contoured surfaces of various configurations. Such functions are accomplished by slowly feeding the workpiece into the equispaced multi-edge circular cutting tool rotating at relatively high speed.

Hence, the need to design and fabricate low-cost and efficient programmable 3-D milling machine for educational and small-scale operation.

Theoretical Review

Milling machines were initially developed to speed up hand-filing. They first appeared in the early 1800s (1814-1818), although it is difficult to trace the exact history because there was much development in small shops at the time (Diaz et al., 2011). The 1840s - 1860s brought the creation of a few popular designs, many of which were geared towards production. They still did not have the classic three axes of movement we know today but were more similar to a drill press, often set up in a line where each machine performed a single operation.

In 1861, Brown & Sharpe created the groundbreaking Universal Milling Machine, which could mill complex part geometries with movement in three axes. From there, production took off as WWI approached. Milling technology developed rapidly for the next few decades, and the introduction of high-accuracy machines like the Jig Bore set the standard for milling accuracy (Bohez, 2002). Now machinists could quickly and accurately locate holes with great precision, making mills commonplace for prototyping and producing wartime equipment. This rapid development continued into the post-war period, during which a few key technologies developed, including anti-backlash nuts, which led to even greater accuracy.

In 1936 Rudolph Bannow conceived the Bridgeport milling machine, which is still in production today. It was lighter, cheaper, and easier to use than many milling machines on the market at the time and became an instant success (Hung et al., 2011). Its success inspired others to copy the design, which led to numerous clones.

During the 1950s, N.C. (Numerical Control) finally moved from the laboratory into the machine shop, with machinists using punched tape to direct the milling machine's movements. Initially, NC machining was used only in aerospace applications, where recreating complex airfoil and wing profiles proved challenging to do reliably. It caught on slowly elsewhere but accelerated into full CNC (Computer Numerical Control) in the 60s and 70s when data storage and input methods improved. Since then, the technology behind data storage, computing, and machine tools has constantly improved, so we can

now have CNC machines at our desks or use them to create giant, complex parts out of many materials (Lamikiz et al., 2008).

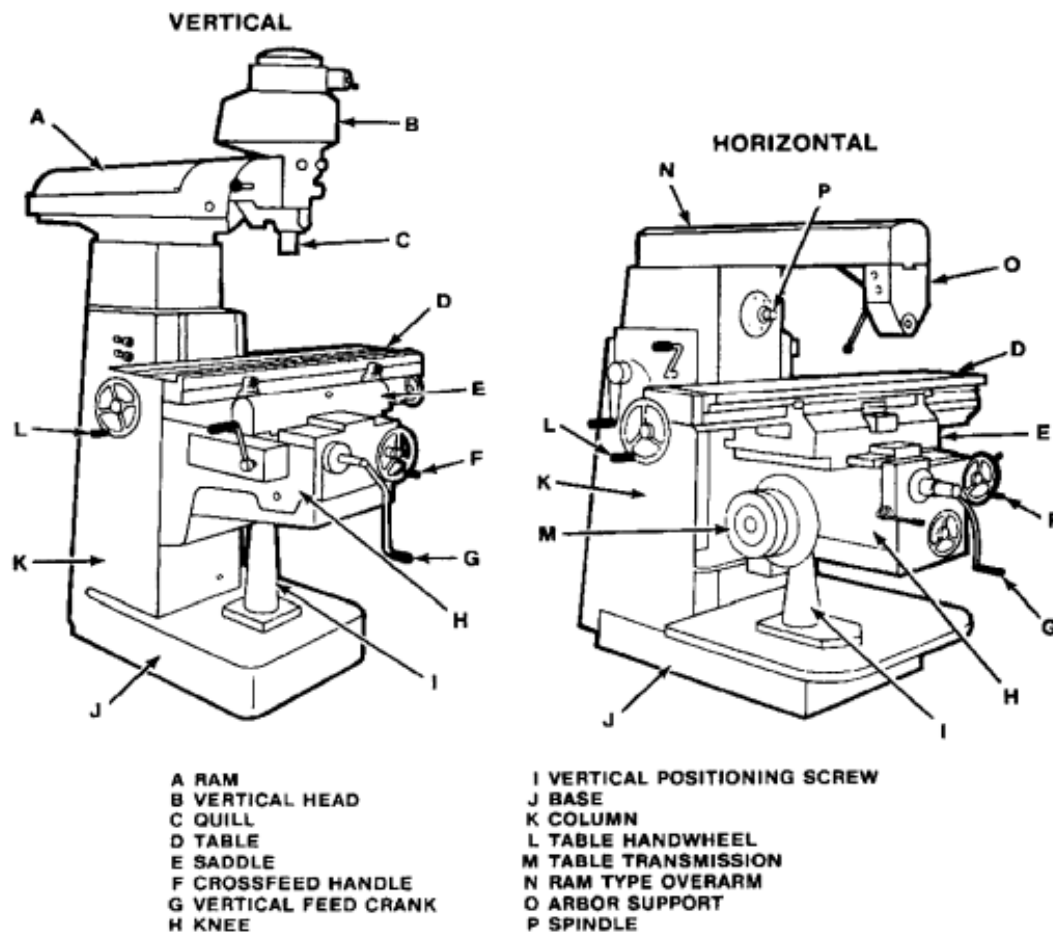


Figure 29: Manual Milling Machines [9]

Types of Milling Machines

Although three-axis milling machines are most common, specific applications may demand additional axes. Not all three-axis machines are capable of the same thing, either. This is where machine control comes into play. Three-axis mills can translate in three directions: X, Y, and Z. Depending on the hardware or software that's controlling the machine, however, it may not be able to move all three at once accurately, necessitating the terms "2.5D" or "2 + 1" milling (Bohez, 2002). This indicates that, although the mill can cut using all three of its axes, it cannot complete moves that utilize all three axes at once. For example, instead of performing a smooth curve in 3D space, they would have to move first in X and Y and then in Z separately.

Another common distinction between milling types is "3 + 2" milling, which describes how specific five-axis machines perform their moves. In this situation, the two rotary axes are often used to orient the part correctly and for the ideal tool angle, while the three normal axes are used for milling. "Full five-axis" does the same, but simultaneously, with all five axes moving at the same time. This requires more complex CAM but will save much time during a long job and likely provide better surface finishes, thanks to the lack

of start-and-stop motions (Bohez, 2002). In this project, a 3-D programmed milling machine will be designed. The machine will utilize computer-aided programs and Solid Works software. A simulation will be developed through the software, which will be fed to the machine using G-Codes (Badamaski, 2014).

6.0 MATERIALS AND METHODS

Materials

1. 3 NEMA 17 stepper motor to control the motion of the cutting tool in the X, Y, and Z axes. They have an accuracy of 1.8° since each point can take 200 positions in one revolution.
2. 12VDC motor is responsible for rotating the drill bit and cutting the workpiece. The motor has a rated speed of 2000 rpm under 12V, 2A power source.
3. Microcontroller (Arduino Nano microcontroller and stepper motor shield) to control the motion of the drill bit through the stepper motors.
4. Computer - the User Interphase Unit, responsible for receiving input from the machine operator and sending the data to the microcontroller.
5. M.S. lead screws to transform the rotational motion of the stepper motors into lateral motion, enabling the support for the drill bit motor to move either horizontally or vertically.
6. Work holding table - a medium for placement of the workpiece.
7. Milling tool responsible for cutting the workpiece.
8. Data transfer cable for transferring data between the computer and the microcontroller.
9. CAM software for actuating the motion of the cutting tool.
10. 12v power supply.
11. 1" M.S. Square tube for fabricating the frame.

Method

Design set up of the programmable 3-D milling machine

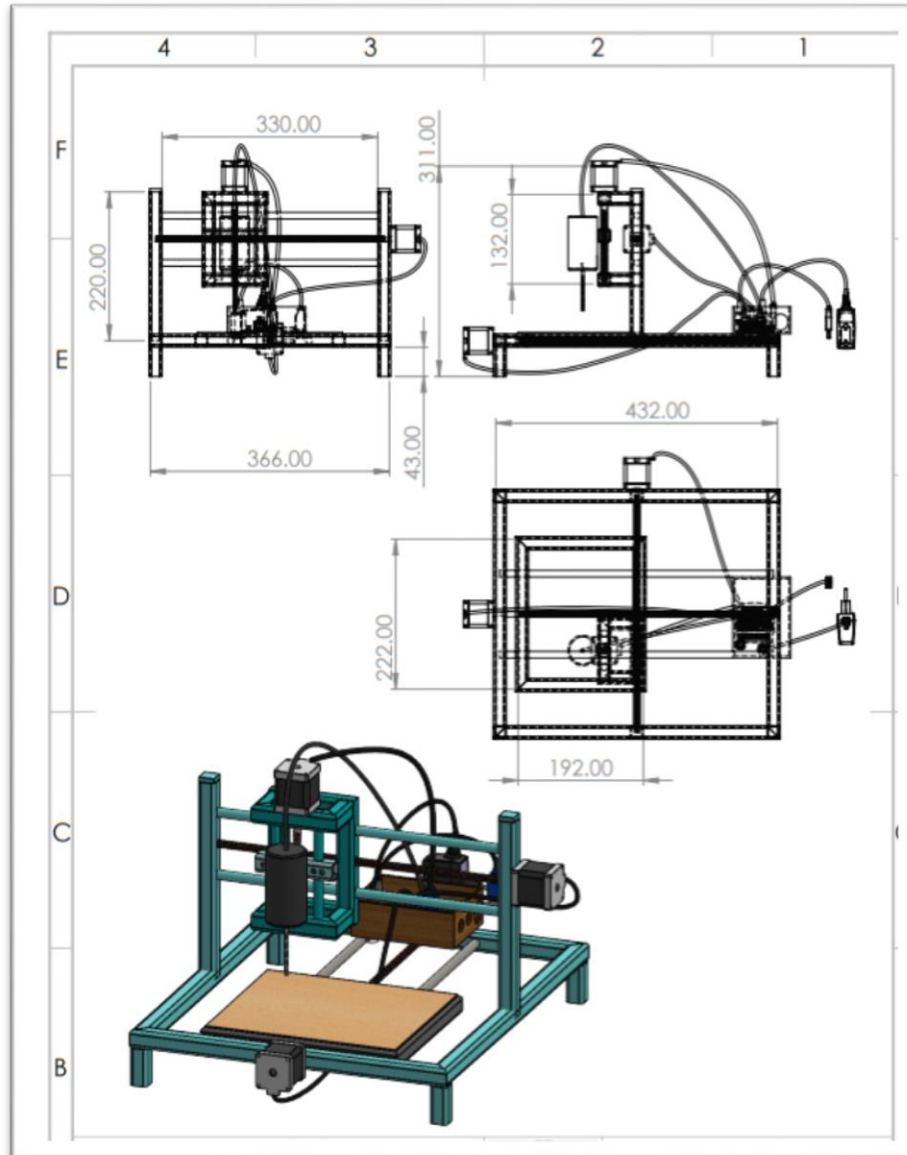


Figure 30: design set up of the programmable 3-D CNC milling machine

Design of the frame

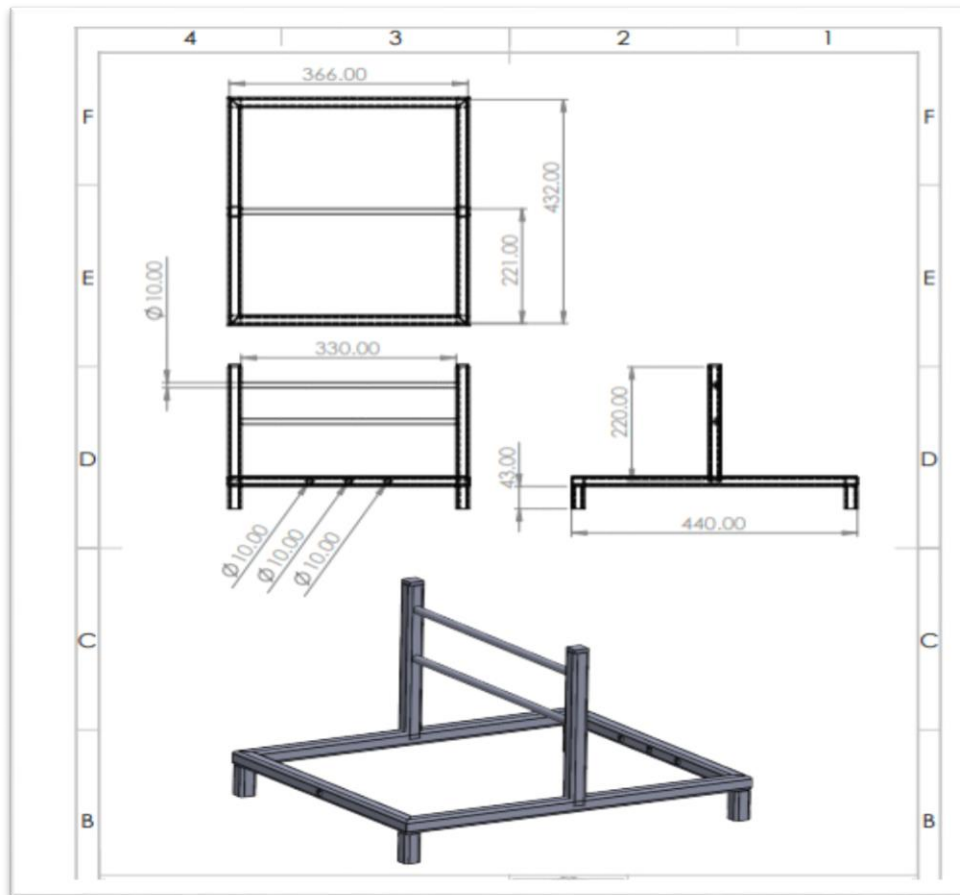


Figure 31: Design of the frame of the CNC

Design of the spindle motor holder

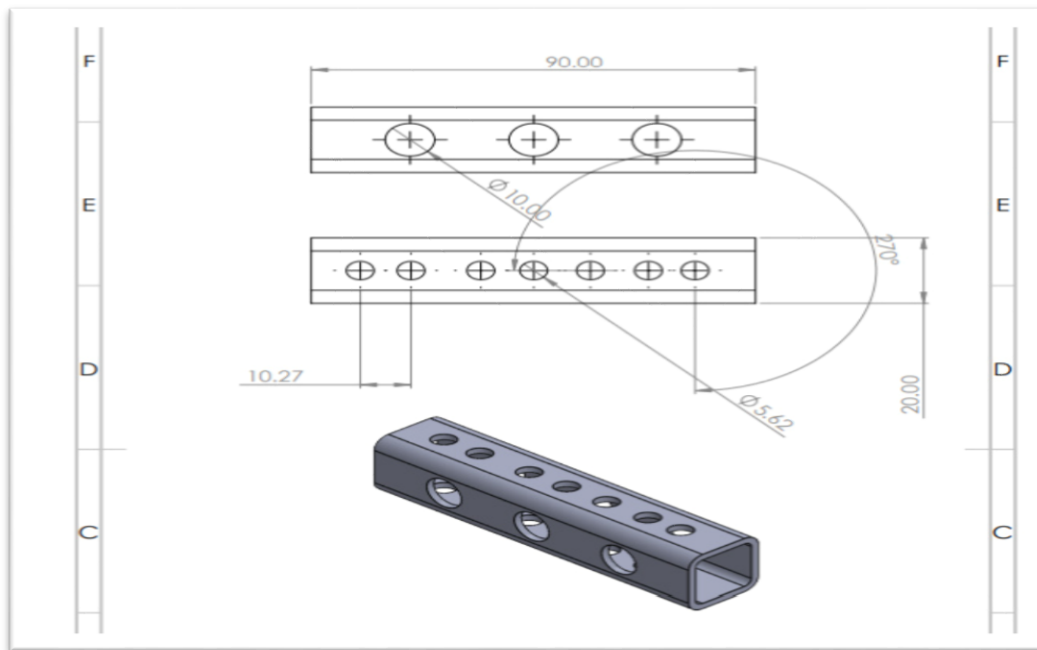


Figure 32: Design of the spindle motor holder

The stepper motor

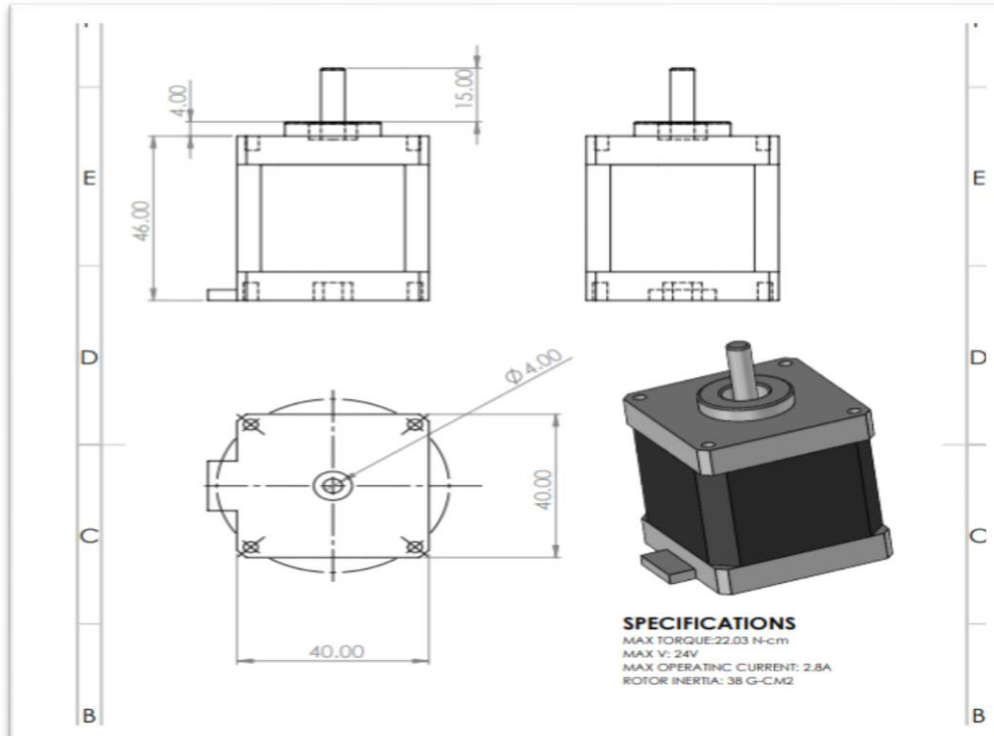


Figure 33: The stepper motor specifications

Design of the X travel bracket

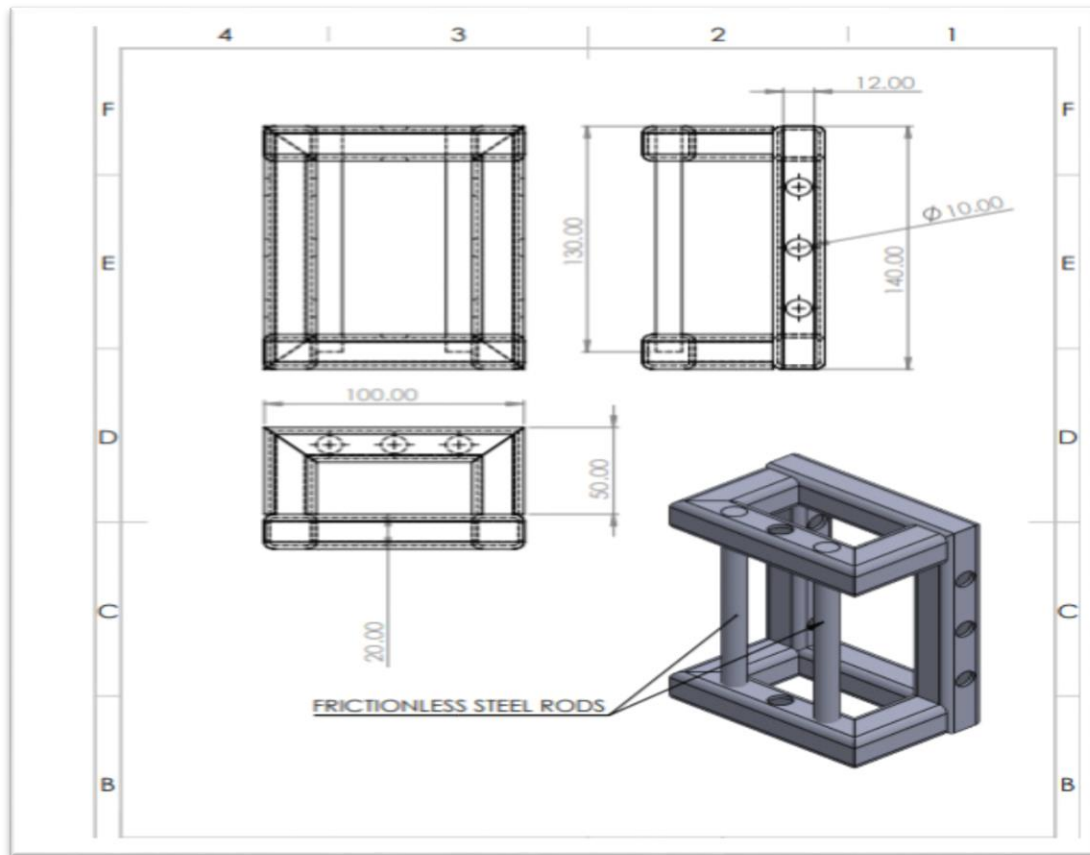


Figure 34: X-Axis travel bracket

Pictorial drawing of the assembly

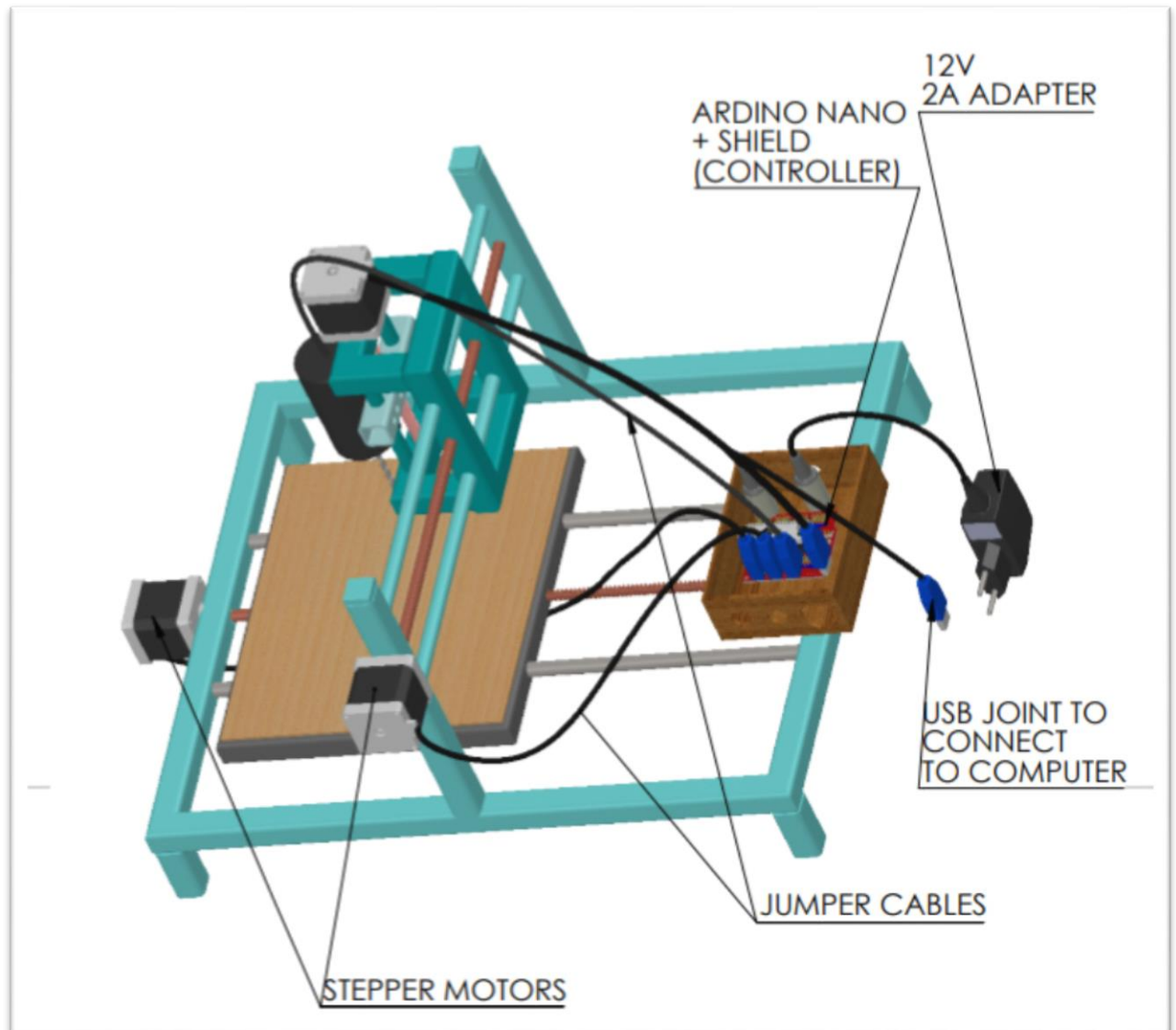


Figure 35: Pictorial drawing of the assembly setup

Experimental Procedure

1. As shown in the engineering drawings, the 1-inch square tube was cut into pieces. These pieces were drilled to make 10mm diameter holes for insertion of the travel rods. The pieces were then welded together to form the frame and X travel platform with travel rods included.
2. M8 threads were cut on the mild steel rods to make the lead screws.
3. Coupling the lead screws to the stepper motors.
4. The X travel platform was fixed to the frame. The stepper motors, once coupled to the lead screws, were then attached to the frame and X travel platform in their respective axes.

5. Once the mechanical part of the machine was fabricated, the software was set in the following sequence.
6. Installing Arduino IDE
7. Installing CAD
8. Installing CAM
9. Installing the G-Code sender software
10. Machine connections
11. Cable connections
12. The stepper motors are connected to the Arduino CNC shield, and the Arduino is connected to the computer through a USB cable. The CNC shield is then powered through the 12V adapter. Once these connections were done, the next step was to connect the G-Code sender software to the GRBL firmware in the Arduino.
13. Software connection

7.0 Results and discussion

Design and Fabrication of the 3-D milling machine

The 3D milling machine was designed and fabricated using locally available and affordable materials. This was to reduce the machine's production cost without compromising its functionality by the desired design specification. The prototype is shown in the plates below.



Figure 36: 3-D Programmed Milling Machine



Figure 37: Picture of the 3-D programed milling machine

Testing of the Milling Machine

The following parameters were tested for the 3D milling and the results compared to the conventional milling machines.

1. Time - program generation, setup, feeding the desired component through the desktop
2. Efficiency - accuracy of operations, convenience

To attain this a CAD software (SolidWorks) was used to design a simple hexagonal shape that was machined, as shown in Figure 10.

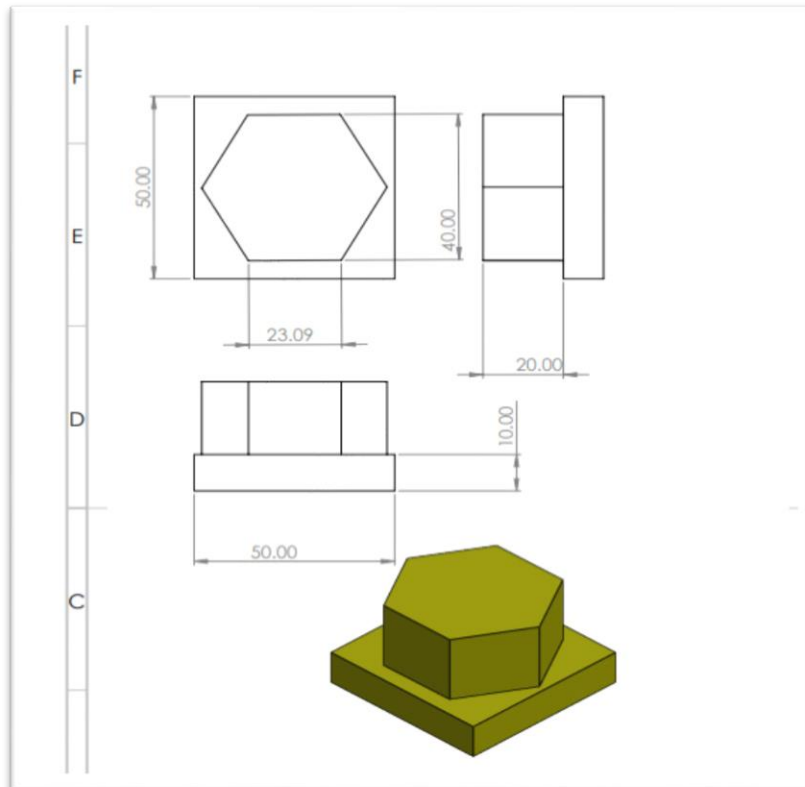


Figure 38: CAD of the part to be machined

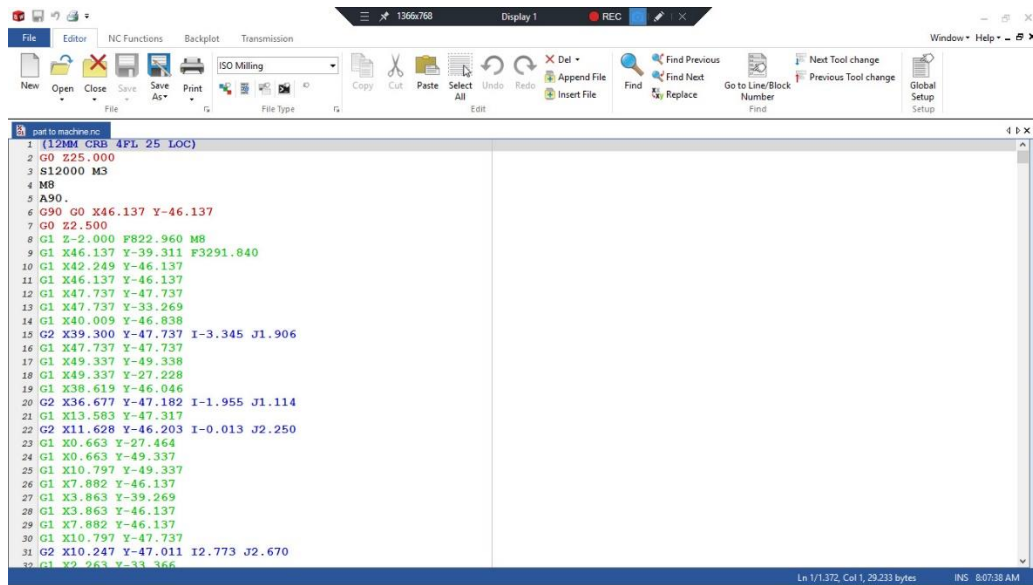


Figure 39: Figure 5- G-Codes generated for the hexagonal part to be machined



Figure 40: The 3-D Programmed Milling Machine under operation

Table 12: Comparisons between 3D milling vs. conventional milling techniques

Deliverable	Findings
Machining Time	3D < than traditional milling
Number of Workforces	1 Person in 3D: Traditional requires two people for positional changes, especially for larger workpieces.
Efficiency	3-D is highly efficient due to limitations in disruptions during workpiece adjustments in traditional machining.
Accuracy	+/- 0.01mm for 3D programmed and 0.1mm for traditional milling

The results attained through the completion of this project indicated that the 3-D programmed milling machine is more efficient as compared to the traditional milling machines. When comparing machining time, setup time, time spent changing positions, and feeding time were considered. Eventually, it was established that the 3-D programmed milling machine spends less time in completion of the operation as compared to the traditional milling operations. In terms of efficiency, fewer disruptions are incurred during the operation of a 3-D milling machine, thus increasing its efficiency. Generally, the designed machine has a very high accuracy of more +/- 0.01mm.

8.0 Conclusion

The machine will be an important learning tool for classrooms and a resource to expose students to manufacturing technologies. It also serves as a level of comparison to available products in the market. Lastly, the machine fits with personal manufacturing by having a smaller footprint, easy operation, and interchangeability of the processes and enabling students to understand the dynamics of milling operations. Additionally, more significant model components can also be assembled, enabling easier machining operations to occur. With this project, manufacturing can increase significantly, as more people can own home-based milling machines, which are easier to operate.

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Robotics and 3D Printing Technologies in Leveraging Practice-oriented Teaching

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Abstract

3D printing has the valiant potential to become one of the 21st century's revolutionary technologies. This technology will, arguably, revolutionize design, end traditional manufacturing, and impose geopolitical, socio-economic, environmental, security, and demographic implications. The digital economic revolution has significance for formal job creation for the marginalized youth. Similar to the Internet of Things (IoT), 3D printing has been known to disrupt manufacturing. While the use of this technology is not yet ubiquitous, it represents the novel chance to circumvent manufacturing limitations and export challenges in resource-limited settings of the Global South. Since there is a limited supply of donor human organs and tissues, models from 3D printing can be adopted to train new surgeons in areas such as better rehearsal of the correct surgical route, prosthesis planning and implant, tactile understanding of anatomy, surgical guidance, intraoperative access, and better patient-surgeon communication. 3D prototyping is an innovative technology that can leverage practice-oriented teaching in academic institutions in Africa. Interestingly, few universities and research institutions in the Global South countries have embraced this technology.

Key Words: Robotics, 3D Printing, Prototyping, Computational Algorithms, Additive Manufacturing, Prosthetics, Digital Economy, 6th Industrial Revolution

Introduction

Widespread technological advances in digital technology have boosted digital fabrication (Kostakis et al., 2018; Nilsiam and Pearce 2017). 3D printing technologies, the Internet of Things (IoT), and Industry 4.0 promise immediate impact on the quality of lives through single factors, constant change, and development (Kumar et al., 2020; Song and Wang, 2018). 3D printing technology uses Computer-Aided Design (CAD) to fabricate the technology of three-dimensional (3D) prototypes and products (Syed et al., 2017). These products improve the quality of life hence shaping individual and communal needs. Subsequently, more sophisticated, interesting, and helpful advancements push the urge to fabricate further, hence new efficient 3D printers being released (Rojek et al., 2021). 3D printing is comparatively cheaper than other parallel technologies such as machining, forming, casting, mold making, milling, and mass production (Alaimo et al., 2017).

Multifactorial aspects, including printer preparation and model dimensions (Chacón et al., 2017); choice of optimal temperatures (Huynh et al., 2017); printing speed (Mohamed et al., 2016); processing parameters (Murr 2014), influence this lower cost. Other factors include model volume and object sizes (Samykanon et al., 2019; Rashid 2018), prototype internal space (Tabacu and Ducu 2018), and printout time (Padhi et al., 2017). Working hours and printer operation procedures (Singh et al., 2017; Peng et al., 2014), availability and occupancy of printer data (Raut et al., 2014), and post-printing modifications, electric cost, and operator cost (Verbeeten et al., 2020; Tanoto et al., 2017) are also contributors. The key difference between 3D printing and traditional technologies is that it uses additive manufacturing techniques while traditional methods apply to thin material from the main block (reductive in nature).

History of 3D Printing

The inception of 3D prototyping was initially in the 1980s, known as Rapid Prototyping (RP) technologies. The name was from the conception that the processes were cheaper and faster in generating industrial product prototypes. In May 1980, Dr. Kodama from Japan got the first patent for this. However, it was termed miss-filled later, hence invalid. However, in 1986, Mr. Charles Hull filed a patent for stereolithography apparatus (SLA) that was first invented in 1983 based on 3D Systems Corporation (Think3D Team, 2015). In 1987, SLA-1 became the first commercialized RP system of the 3D Systems.

Additionally, Mr. Carl Deckard, from the University of Texas, filed the Selective Laser Sintering (SLS) RP process patent in the US that same year. The patent was effected in 1989, and later, SLS was licensed under DTM Inc, acquired later by 3D Systems (Think3D Team, 2015). Mr. Scott Crump filed another patent in 1989 for Fused Deposition Modeling (FDM), who later co-founded Stratasys Inc, a major 3D printing company. By 2015, FDM had reputable popularity as an entry-level 3D printing technology. The technology uses the open-source RepRap model, and the patent for it is dated 1992. In Europe, Hans Langer founded EOS' GmbH in Germany in 1989. Its mandate focused on the Laser Sintering (LS) process, which has grown exponentially to its current reputation globally as a significant contributor to quality industrial prototypes and 3D printing applications. EOS sold the first 'Stereos' systems in 1990. Its Direct Metal Laser Sintering (DMLS) process was a concept of an original project collaboration with Electrolux Finland that later was acquired by EOS (Think3D Team, 2015). Other technologies of 3D printing that emerged during this era included Michael Feygin's Laminated Object Manufacturing (LOM), William Masters' Ballistic Particle Manufacturing (BPM), Solid Ground Curing (SGC) patented by Itzhak Pomerantz and Emanuel Sachs' 'three-dimensional printing' (3DP). The early nineties witnessed immense RP-based competition from companies with only three that still stand today, i.e., EOS, 3D Systems, and Stratasys (Think3D Team, 2015). R&D led to more enhanced technology providers for specific tooling, casting, and direct manufacturing in the 2000's. Emerging technologies included Rapid Casting (RC), Rapid Tooling (RT), and Rapid Manufacturing (RM), respectively. Commercially, Sanders Prototype (later Solidscape) and ZCorporation were set up in 1996, Arcam 1997, Objet Geometries 1998, MCP Technologies in 2000 (for vacuum casting OEM) brought SLM technology, EnvisionTec

2002, ExOne 2005 as an alternate of Extrude Hone Corporation and Sciaky Inc. featured its additive process based on proprietary electron beam welding technology. Other than swerving the Wesren companies' ranks, they influenced the metamorphosis of the terminology to Additive Manufacturing (AM) (Think3D Team, 2015).

3D Prototyping and the Fight against COVID-19

The uncertainty created globally by the COVID-19 pandemic has brought a crisis that is still unfolding. Challenges arising from disruptions in manufacturing and transportation, efforts against globalization, and free trade creates hindrances in supply chains, resulting in critical shortages of vital materials needed by the healthcare system. 3D printing technology has redeployed its capabilities in the fight against COVID-19 responses, thus exhibiting highly competitive merit in the occurrence of an emergency. The crisis has illuminated how 3D printing can be used to create a more environmentally friendly and greener future. The advanced and rapid prototyping of 3D printing enables rapid response to emergencies through swift technology mobilization. In instances of severe supply chain disruptions, crucial parts can be manufactured on-demand by sharing designs online, thus decentralizing the 3D printing facility.

Additive manufacturing creates room for complex product designs and customization. 3D printing has been widely applied in the fight against COVID-19, for instance, in the manufacturing of personal protective equipment (PPE), personal accessories, medical and testing devices, emergency dwellings to isolate patients, and visualization aids (Bishop and Leigh, 2020; Iyengar et al., 2020, Callahan et al., 2020; Wang et al., 2019). Owing to a deficit of ventilator machines, continuous positive airways pressure (CPAP) machines have been used as substitutes for COVID-19 patients in need of sub-intensive therapy. 3D printing is also being used to manufacture 3D printed nasopharyngeal swabs fabricated with complex tip structures for improved efficacy in sample collection, hence is no need to apply flocks at the tips. Additionally, both 3D printing and 3D scanning have been employed in the making of personalized 3D printed face masks with an ergonomic fit, unlike standard masks that are not fitted to the individual facial anatomy, which can consequently provoke skin pressure ulcers when worn continuous (Gefen et al., 2020; Shaheen et al., 2020). This technology also can replicate highly accurate models of human anatomy via the 3D printing of medical manikins that are life-sized. The models can be applied in training to allow healthcare workers to practice COVID-19 swab testing procedures with standard medical-grade swabs. Therefore, it is crucial to maintain a high confidence level by ensuring technological suitability and accountability of new approved designs and certified materials.

The onset of the COVID-19 pandemic stretched the urgency of specialized and medical products' needs, more so personal protective equipment (PPEs). The disparity between demand and supply of the products out-ran conventional production has a greater desire for quick, cheap, and easy fabrication. Manufacturers opted to address this through 3D printing. Previous designs have been customized to befit 3D printing requirements to help fill the deficit in the fight against COVID-19 (Payar et al., 2021). Countries across the world have been encountering a shortage of supplies of COVID-19 supplies among essential service providers and the public (Mahase, 2020; Feng, et al., 2020). Given this

shortage and PPEs' importance, global designers proposed various 3D printed devices to help in prevention the general global spread of the virus (Michael, 2020). 3D printing companies, such as Prusa, Formlabs and Stratasys, have developed designing protocols for face shields and availed them online (Armijo et al., 2021; Prusa, 2021; Formlabs, 2021; Stratasys, 2021). Most current face shield designs have a 3D printed headband, fitting for the user's head, designed to support a front plate/visor made from any laser-cuttable plastic that is clear (Prusa, 2021). Main facemasks focus has been on snorkel and scuba masks to those using conversion (Livingstone et al., 2020; Liang, 2020; Emmott, 2020). The conversion, when 3D printed, is miniature, able to connect with a filter and very affordable, even though it does not require the user to access the mask or filter papers to fit in them. Gadgets and tools limiting physical contact have also been 3D printed. They include hands-free door handles for elbows/feet-driven opening and small gadgets used for pressing buttons in public areas (Michael, 2020). Scuba diving masks were converted to ventilators through 3D conversion that can be adopted and linked to oxygen tanks (Formlabs 2020; Lisickis, 2020). Companies including Huaxiang, Farsoon and LEHVOSS designed, validated, and made availed downloadable files for two sizes of safety googles to be made by SLA, SLS or FFF technologies.

3D Printing in Upheave of Digital Economy

Digital economy which is mainly based on digital computing technologies, is highly being revolutionized by 3D printing technology. Transformational changes are occurring in the way businesses produce, deliver and consume goods and services in a rapidly expanding digitalized marketplace (Campbell et al., 2011). Consequently, the digitalization of the economy is changing the behavior of economic agents. 3D prototyping is useful in creating digital 3D models of the real world which include construction companies, production of oil, service enterprises and manufacturers of complex technological products. Additionally, 3D modeling also encapsulates filling of data thus optimizing management and decision-making processes (Ugli and Mukhiddin, 2020).

Additive manufacturing has the potency to be a disruptive technology like the internet and personal computer. This digitization of physical artifacts creates room for increased and easy distribution of designed solutions worldwide hence minimizing the barriers to manufacturing creating an opportunity for everyone to become an entrepreneur (Campbell et al., 2011). As much as digital distributed production is still obscure to many, it is astounding how it is taking over the modern industries. One manifestation is Gearbox, Kenya, a maker space facility, which develops local skills and offer a helping hand in prototype manufacturing and small-scale production by employing 3D prototyping and other manufacturing technologies (Bolwijn et al., 2018).

A Case Study on Practice Oriented Teaching in MMUST.

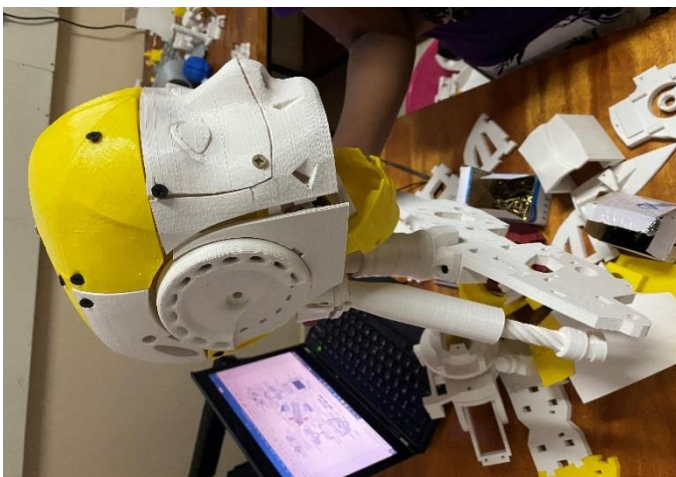
The idea of 3D prototyping was inspired by the desire to produce prototypical illustrations of scientific systems in the university, able to perpetually infer curious, intellectual brevity and critical thinking among learners with unquenched thirst for technical knowledge. The purpose was to nurture critical-thinking problem-based learning.

Summed up, these proficiencies were construed to have the power to engender a new generation of innovators with tremendous influence on the learner, laying a foundation for robust thinking and pioneering cutting-edge advancements in basic science and medical research. There has been a broad consensus that inquiry-based instruction can radically transform higher education sector, especially where technology is blended into data manipulation as an important tool in inquiry-based instruction. Masinde Muliro University of Science and Technology (MMUST) has advanced its innovative capacity via collaborative research and training program with Brandenburg University of Applied Sciences and the University of Applied Sciences Magdeburg, Germany.



Figure 1 & 2: MMUST has enhanced its innovative capacity through collaborative research and training program with Brandenburg University of Applied Sciences and the University of Applied Sciences Magdeburg, Germany. This collaboration has yielded MMUST a state of the art 3D printer, the Makerbot Replicator Plus

Robotics



Ground laying robotics improvement has extended human sensory experience, and cognition to an unprecedented level. Robotics in human augmentation has made it possible that going forward humans will be much faster, stronger, less prone to injury and highly productive. 3D printing can now compensate for varied disabilities in humans and elevate human capability beyond their innate physiological levels thus enabling them to perform different sets of tasks with both anthropomorphic and non-anthropomorphic extended bodies. 3D printed robotic has yielded seminal discoveries within the emerging science of human augmentation, addressing the scientific principles that underlie novel robotic technology.

a) The Robotics Arm

Training in robotics for simulating biological processes made significant contribution in the practice oriented teaching and helped uphold the development of new theoretical frameworks, paradigms, and tools for teaching besides opening up opportunities for entrepreneurial education for students in Kenya. Robots as tools for the development of new hypotheses amenable to experimental tests of a biological nature is an interesting area, especially in STEM subjects. 3D printing of robotics in simulating biological processes including printing of robotic arms and robotic prostheses is an inexhaustible and illuminating source of inspiration in STEM teaching at our university. In the area of autonomous and intelligent robot systems focused on copying biological systems and dynamic simulation is a critical skill area for curious students. This lead to new ideas and novel technologies that helped in closing the current gap between natural and artificial intelligence, one of the areas that puzzle many learners.

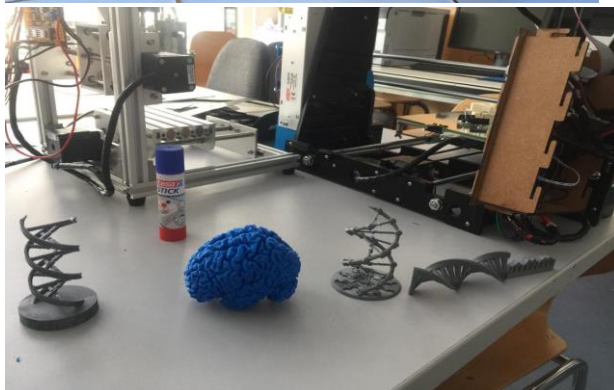


Figure 3 & 4: The 3D printed robotics arm built for MMUST by University of Applied Sciences Magdeburg under the direction of Prof. Dr.Ing. C-T, Weber and assorted Molecular biology simulations of the human brain, DNA and RNA made at MMUST.

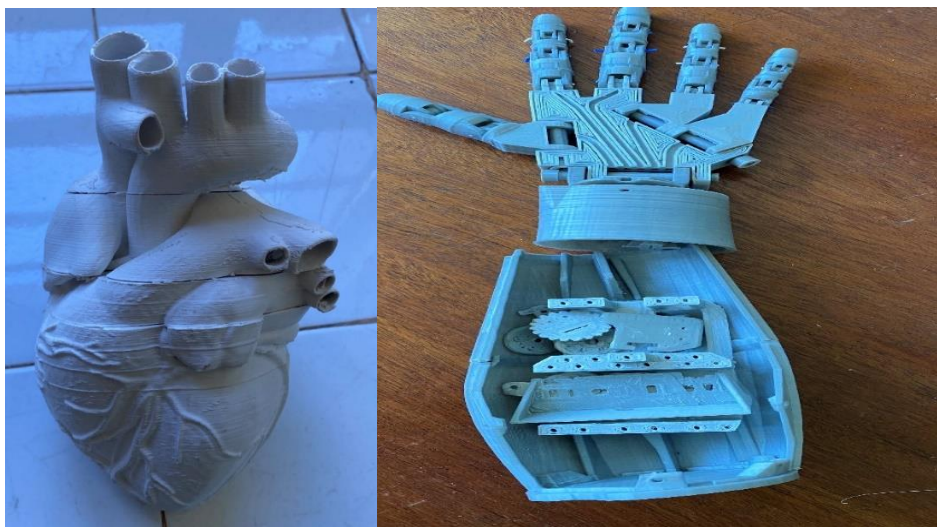


Figure 5 & 6: 3D printed human heart and prosthetic arm at MMUST

The use of robots for testing biological models and the running computational processes on it, is a skill area in which most students are inadequate. However, coupled with previous 3D prototyping, computational and bioinformatics, training in biological robotics has opened up new horizons for learners at MMUST.

Within the context of cognitive science, the utilization of evolutionary algorithms to generate robot behavior for simulation of real robot systems inspired learning. 3D modeling was integrated in the robotics project and computing, providing a deeper insight into the complexity of how different biological systems interact. This made learning more interesting since 3D printing of robotics is an eclectic area of science today. 3D printing has had tremendous application in education/research and medicine with profoundly transformative consequences. It has revolutionized the current narrow-deep linear learning methods often construed as tedious with limited interactive learning. Theoretical concepts have failed to yield concrete prescriptions for classroom and real life applications.

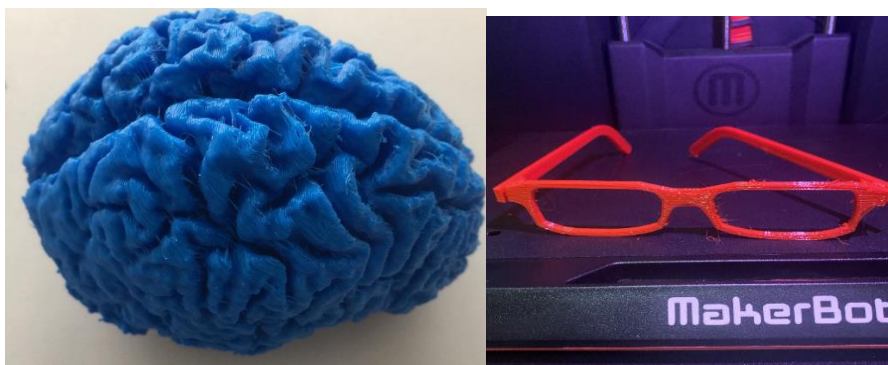


Figure 7, 8 & 9: 3D printed human brain, prosthetic arm and goggles

Many scholars now agree that the concept of education needs restructuring so as to attain the ultimate goal of learning and associated teaching in technical and sciences subjects that is, to acquire adaptive expertise, the capacity to flexibly and creatively apply the learned knowledge in the society. For this reason, experiential learning is gaining traction globally in disciplines that were previously inherently hands-on alongside those that require proxies and models. In courses like computational and molecular biophysics, regenerative medicine and tissue engineering, 3D modeling is making it easier to visualize and externally manipulate macromolecular structures and or scaffolds, creating millions of virtual off-site laboratories where a student can virtually take a walk and generate plausible research data.

Applications of 3D Prototyping

A.) Medical and Healthcare Application

Complex anatomical surgeries of the human body have always been a challenge to surgeons. Multi-detector computed tomography (MDCT) and magnetic resonance imaging (MRI) have made diagnosis more informative and less invasive through modern imaging. The two generate 2D (two-dimensional) images of high-resolution. However, they are inaccurate or limited in deciphering complex 3D structures. Virtually, 3D reconstruction techniques impose volume or surface rendering, for enhanced structural complexity understanding through model rotation or layer sectioning off the virtual 3D model. This is vital in visualization of complex structures, and diagnosis of aneurysms and congenital heart defects (Spevak et al., 2008; Ou et al., 2007; Kellenberger et al., 2007). Nevertheless, differences between the interplay of real anatomical and the 3D virtual interpretation is still challenging hence a surgeon's expertise and experience proofs are reliable here (Shiraishi et al., 2010). 3D printing is now being adopted to address the limitations of 3D imaging by way of physical modeling of anatomical representations to simulate them and allow for preoperative planning.

CT data and MRI angiography have been employed in cardiology to fabricate 3D models. SLA has been applied in research, to model congenital heart disease (CHD) characteristic complexities like severed pulmonary vascular tree (Ngan et al., 2006), intra-cardiac lesions and complex vascular pathology (Sodian et al., 2007). Further, FDM has also been successful in modeling various cases of cardiovascular anatomy (Valverde et al., 2017). Through this proof of concept studies, rapid prototyping has shown a +95% model accuracy for cardiac surgery applications, (Mottl-Link et al., 2008; Noecker et al., 2006; Jacobs et al., 2008). The first conceptual rapid prototyping in neurosurgery consisted of, virtually simulated, MRI/CT data, followed by anatomical 3D printing for the rehearsal and final surgical plan refinement. Recently, interactive virtual simulation (IVS) (virtual reality pre-surgical simulation) combined with 3D printed models demonstrated importance in preoperative planning and rehearsal in cases of deep tumors and skull base (Oishi et al., 2013).

3D printing has been adopted in implant pre-shaping for bilateral craniomaxillofacial posttraumatic deformities, other than simply serving as a model reference (Cui et al., 2014). Here, SLS models of the skull were fabricated location determined through rehearsal surgery, reduction direction, and shift distance of the osteotomy. 3D printing

(SLA) for a case of a right shoulder injury with possible clavicle and scapula double fracture has been described in research (Potamianos et al., 2015). Further, studies by Brown et al.(2003) through 3D printing as guide to correct and understand several cases of spine pathology, severe acetabulum fractures, and fractures of the ankle, foot, tibia, pelvic ring, shoulder, femur, arm, knee and wrist. Through the studies, the 3D models demonstrated better appreciation of degrees of anterior fracture displacement of fragments and injury classification by reduced inter-observer variability. Other medical applications include: cheap replication of natural structure of the skin that can be adopted to test cosmetics, pharmaceuticals and other chemicals using animal skin for accurate results (Qian et al., 2018). Pharmaceutical companies use 3D printing drug design to increase efficiency, high reproducibility, accurate size and dose and complex drug-release dosage form profiles (Ventola, 2014). Through 3D printing, bone and cartilage is printable to replace bony voids in the bone or cartilage through trauma or disease (Bogue, 2013). This technology avails accurate and reliable data in the simulation of a patient's pathological condition.

B.) Fashion Industry

Utilization of 3D prototyping in fashion industry is becoming a reality worldwide, for instance, making of 3D printed shoes, jewelry and clothing. This technology has led increased innovativeness in fashion design where designers are able to offer personalized and unique products based on customers' specifications. Additionally, an individual's body can be scanned and personalized clothing be customized accordingly (Chakraborty and Biswas, 2020). Garments can be produced using 3D printing via a mesh system and in addition print ornaments for traditionally designed textile. Shoe making Companies, e.g., Adidas and Nike, are doing mass production of 3D printed athlete's shoes, custom-made shoes and sneakers (Shahrudin et al., 2019). Continuum as a retailer offers customizable 3D printed products like jewelry, bathing suits and shoes. Furthermore, haute couture designers have used 3D printed intricate accessories and dresses on the runway (Vanderploeg et al., 2017). The technology is weighty in reducing the cost and time of supply chain.

C.) Food Industry

Additive manufacturing is now being applied in food production using printers purposely designed for food fabrication (Mantihal et al., 2020). Food layer manufacture is fabricated via the deposition of successive layers obtained from computer-aided design data, creating novel food items with fascinating and complex designs (Liu et al., 2017). It is crucial to apprehend food material properties like the rheology, thermal properties, and tribology (Hao et al., 2010; Godoi et al., 2016) to attain high food physical properties and composition's complexity. Novel digital food technologies through laboratory culture meat are emerging to aid environmentally friendly and ethical meat production and in ensuring food safety, food security and environmental sustainability. Meat three-dimensional (3D) printing is a novel technique of food fabrication with great market and application potential in developing a unique food with desired nutritional value. Such foods possess multiple colors, flavors and custom texture for popularity (Mehak et al., 2021). The growing need for customized food for special consumers, for instance, elderly,

athletes, children, pregnant woman and patients calls for the need to invent new technologies. These are usable in the processing of food containing healthy ingredients (vitamins, additives) by reducing the levels of unnecessary ingredients and with increased shelf-life (Godoi et al., 2016). This capability to automatically adjust food ingredients to the consumer's specifications, would make it possible to avail diets enforcing themselves without the need to exercise. Therefore, this is an indispensable high-energy efficiency technology for production of food which gives room for food quality control, protection of the environment and reduces the processing, packaging and distribution costs (Jia et al., 2016). The universal application of food printing technology gives a possibility of broadening source availability of food material, by utilizing non-traditional materials for example, insects, high fiber plant based materials, plant and animal based by-products (Severini and Derossi, 2016). The 3D printing technique currently used in the food sector generally include selective sintering printing, binder jetting, extrusion based printing and inkjet printing. According to Yang et al. (2015) extrusion based printing is applied in the extrusion of hot-melt chocolate, dough, mashed potatoes and other soft materials. Lipton et al. (2010) also studied the use of extrusion based printing in the fabrication of processed cheese, sugary cookies and cake frosting. Results from PERFORMANCE's survey in care homes concerning utilization of 3D printing food indicated that 54% of participants liked the texture of the food, 79% equated the printed food to the traditional food whereas in instances of dysphagia occurrence 43% preferred printed food (Lunardo, 2016).

D.) Transportation

3D printing has revolutionized industries to manufacture new things of varied designs. In the automotive industry, this technology has allowed manufacturing of complex lighter structures. In 2014, Local Motor printed out the first 3D-printed electric car (Joshi and Sheikh, 2015). In addition, BMW produces hand tools used in testing and assembly of automotive via 3D printing technology (Shahrubudin et al., 2019). The technology also has potential for fuel savings from the making of lightweight parts and reduced quantity of material used in the production of aerospace parts. Moreover, spare engines' parts, which are easily damaged, can be made using 3D prototyping (Wang et al., 2019).

Conclusion

3D printing is applicable in almost all of the categories of human needs. By employing it people can increase their social and employment opportunities, regain mobility and possibly alleviate self-reliance and self-confidence. Smart material 3D printing is gaining momentum in interdisciplinary application. Shape memory alloys and self-evolving polymers are such material applications. Surgical domain 3D printing has shown immense rise in the past two decades. This is not fully explored in its use information of soft tissue structures, its mechanical properties and high-resolution anatomical features. In food industry, post processing is required to ensure edibility, for the creation of a wide range of printed foods. The technology should be inculcated across board to encourage conceptualization of theoretical aspects of learning, research and industry. The correlation between Artificial Intelligence (A.I), Machine Learning (ML) and computational science should be harnessed in fostering this modern era revolution. In biology, for instance, the simulations have promised to bring learning of systems close to physicality and not just

from an inference-only point of view. Further, given the nature of environmental soundness and awareness, more research into friendlier 3D prototyping should be encouraged. This is to help support climate readiness, friendly and sustainability by ensuring the process and products play a role in positive impact.

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Introduction of Practice and Research-orientated Teaching : The Development of E-Health Services in Rural Areas of Kakamega County, Kenya

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Abstract

The article describes the intent to undertake a study through multidisciplinary teaching and learning. The aim is to generate balance data sets from subjects in a university setting. The use of simple sensors and the students' hard and software development will help analyse this data. It will involve student teams from three disciplines: health, computer science, and medical informatics. The data sets will be made available to public data for other studies. The experiment results will present an opportunity of using inexpensive, flexible, and meaningful resolutions to assist in evaluating and monitoring activities, further a platform for students to learn through practice-oriented teaching.

Keywords: Collaboration, Education, Research, Multidisciplinary, Competence, E-health, and Rural Areas

Introduction

The educational level of Kenyan students is very high, but there is a gap between theoretical knowledge and problem-solving competency (Ongesa, 2020). Learning in most institutions has been more of knowledge acquisition than competencies. A discussion of closing the gap between theory and practice is very important. Meanwhile, the goals of a university education process are rewritten from a focus on theoretical knowledge to competencies. Competence is where students demonstrate their learned knowledge and skills to achieve specific competencies prescribed in the curriculum (Sturgis, 2018). There is mastery of competence in competence development and the creation and application of knowledge.

Concerning the new focus of teaching, the new teaching methods used are, for example, problem-based learning, project-based learning, and research-oriented learning.

Between problem-based learning and project-based learning, only slight differences exist. Problem-based learning has a focus more on one specific topic (problem), in contrast to project-based learning with a more complex, often multidisciplinary topic (covered in a project) (Dolmans, 2005). The main aim of both teaching concepts is the development of problem-solving competence, network, and system thinking.

The research-oriented approach focuses on scientific work, including developing a scientific question, the application of an experiment, the evaluation and description of data, and finding a conclusion. The term research-oriented teaching covers different types of the connection of research and teaching: research tutored, research-based, research-led, and research-oriented teaching (Savery, 2006). These types have differences in students' participation (active or as audience) and research aspects (focus on content or process) (Savery, 2006). The main aim of research-related teaching is the close integration of science in the educational process, promoting scientific working and systemic, scientific thinking.

The Project ProUniEdu-WeK (Practice-oriented University Education in Western Kenya) started in 2018 and comes to an end in 2021. As the project's name implies, this project's focus was integrating new teaching methods based on problem-, project-based, and research-oriented teaching in the curriculum. The German Academic Exchange Service supported this project.

Developing practical thinking, systems thinking, and problem-solving competence is one cornerstone to prepare students better for the job market. In this project, the Masinde Muliro University of Science and Technology, the Brandenburg University of Applied Sciences (Technische Hochschule Brandenburg – THB), the University of Applied Sciences Magdeburg, and the Eberswalde University of Sustainable Development (HNEE) work together in the fields of public health, physiotherapy, technology, computer science, medical informatics, and agriculture. Specifically, the cooperation between the Department of Informatics and Media (THB), the School of Computing and Information Science, and the School of Public Health, Biomedical Sciences, and Technology (both MMUST) have emphasized the multidisciplinary collaboration between computer science, medical informatics, and medicine.

Integrating practice into teaching is a central concern of all participating partners. In the practical application of high theoretical knowledge, students acquire the necessary skills to structure problems and develop solution concepts actively. In addition, there is the task of promoting active scientific work. One possibility is to combine practice-oriented teaching with research projects. Developing a health app for rural areas is such practice-oriented teaching enabling communication and cooperation of students in Physiotherapy, Computer Science, and Medical Informatics from Kenya and Germany.

Physiotherapy represents the medical domain. Computer Science and Medical Informatics cover the developmental process of a web app for health management as a telemedical solution.

Activities for the Development of an International Interdisciplinary Project

In the context of the ProUniEdu-WeK-Project, the partners performed different activities:

- Workshops of the teachers: In workshops organized by the different departments, the participants learned some fundamental aspects from the other domain, improving the general understanding of the specific needs of the other domain.
- Workshop with students: Students of medical informatics from THB organized workshops at MMUSTS to determine the specific problems in the context of rural

areas in Kenya, especially Kakamega County. MMUST-Students could experience how students organize their own workshops.

- Visits of county administration, Kakamega hospital, and village: THB-students learned a lot about the health system in Kenya and the living conditions in rural areas.
- Meetings of the teachers were essential to establish the organizational context.
- Videoconferences: especially under the condition of the Corona pandemic, were essential for the follow-up of project work.

These activities were necessary for developing the project-based educational process and the inauguration of the challenge for the health app development for rural areas.

Results

In 2019 the first Kenyan-German Students Challenge took place at MMUST. Four groups of students were from computer science, medical informatics, and physiotherapy worked on four different problems (Figure 1).



Figure 41: An international, interdisciplinary team under discussion

The task was to develop a telemedicine solution based on a web app. The process of the development covered the following:

- the problem description,
- the requirements analysis,
- the development of ideas on how to solve the problem,
- the decision of which idea is the best for problem-solving
- the design and implementation of the WebApp and
- the presentation of the results.

These steps contain all important aspects of project-based learning.

One example is presented here: the Medical Service Network:

The team summarized the main issues and goals of such a network (Figure 2)

Goals

In **rural areas** it is difficult to provide good medical care. Doctors can be found in the larger cities, but are not always available. There is no way for a patient to find out where **which doctors are currently available** and what **their specialties** are. It also makes sense to include other medical forces in the consideration. A tool is needed where, on the one hand, **patients can quickly find out where medical help is available**. On the other hand, there should be the **possibility to manage medical care**.

Additional: possibility of providing emergency help

Figure 42: Description of the goals

They found different ideas and tried to summarize them (Figure. 2).

Ideas

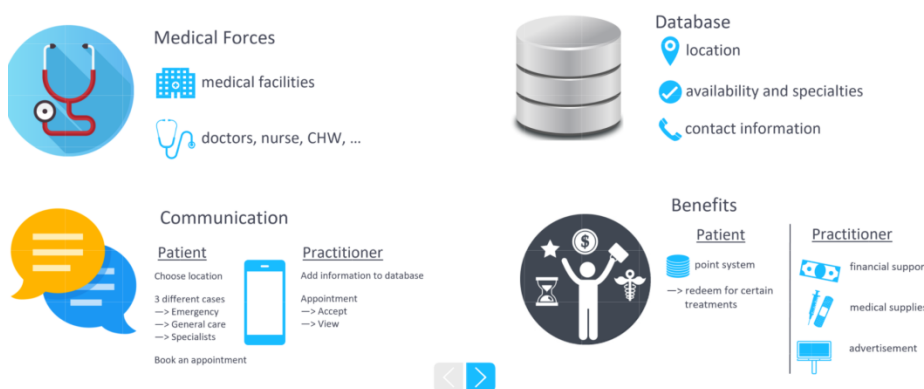


Figure 43: Collecting and structuring the ideas

The team specified various assumptions and limitations (Figure 3).

Assumptions and Limitations

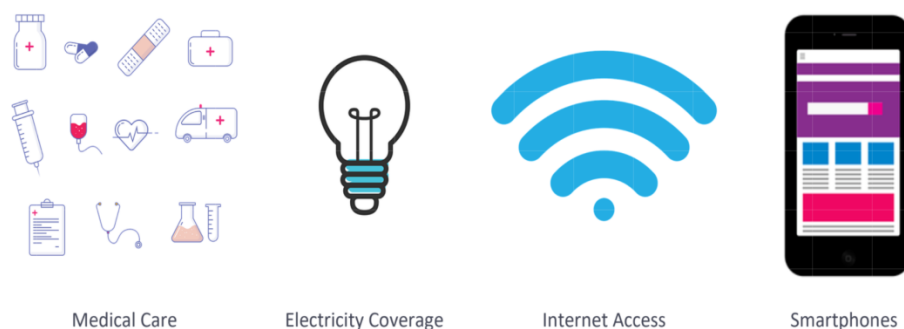


Figure 44: Main assumptions and limitations of telemedical services in rural areas

Finally, the team developed the application for communication between patients and health care providers (Figure 4).

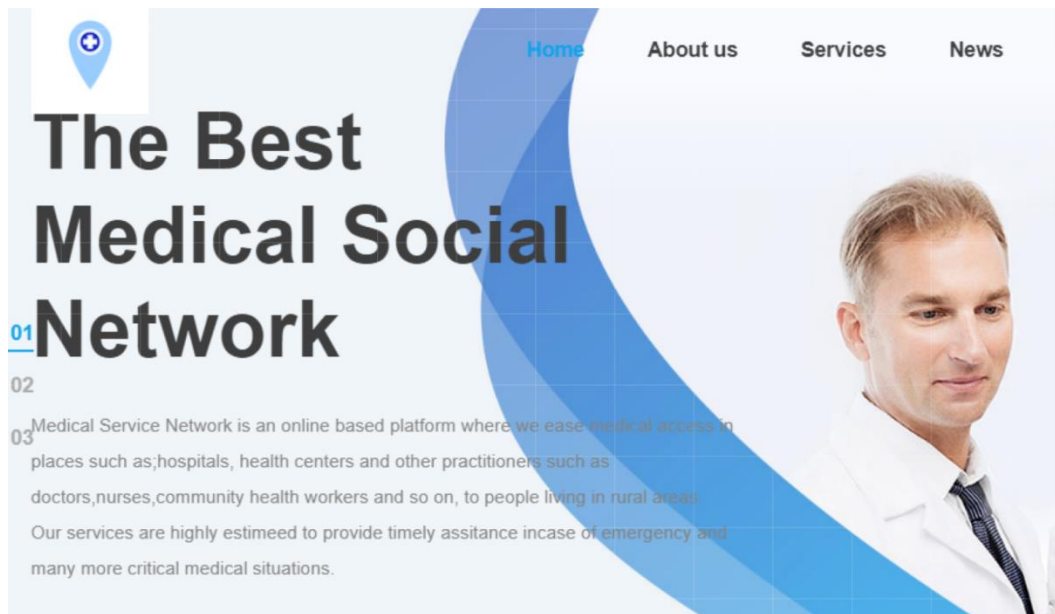


Figure 45: The result - a web app for health care

The challenge was an important experience for all participants (fig. 5). The students could communicate with other domains (and other concepts). The picture below (Figure 6) shows the team involved during the workshop with students of medical informatics (THB), School of Informatics, and School of Public Health (MMUST)



Figure 46: Participants of the first Kenyan German Challenge

The workshops held for students and teachers resulted in understanding the importance of project-oriented teaching and the application of problem-solving skills.



Figure 7: Participants in MMUST at the workshop for students and staff

A visit by THB students to Kakamega County and Referral Hospital and the village: enabled them to learn a lot about the health system in Kenya and the living conditions in rural areas. See figure 8 below of students, staff from THB, and the hospital in Kakamega.



Figure 8: Visit County administration and General Hospital, Kakamega

Conclusion

Through the ProUniEdu-WeK project between MMUST and THB, the use and application of innovative methods of teaching and learning have been implemented in computer science and Health professions programs in MMUST. The departments involved in the project were the Department of Informatics and Media (THB), the School of Computing and Information Science, and the School of Public Health, Biomedical Sciences and Technology (both MMUST) who embraced practice-oriented and research-oriented teaching.

Practice-based and research-oriented teaching prepared the learners to solve health problems and find solutions to health problems. One of the problems solved is accessibility to health care services by developing Web apps for rural areas specifically on health problems.

The activities' results also led to the development of the Web application for communication between patients and health care providers. The research activities created interest among MMUST faculty staff in the health sciences discipline to develop e-content learning materials. The new approach for teaching and learning during the COVID -19 pandemic has improved by using the blended mode of learning. This is done by combining face-to-face sessions and the e-learning approach. The process of developing e-learning materials for teaching clinical and practical skills is vital to close the gap between theory and practice. Hence the video conference equipment available will facilitate learning in various settings.

Recommendations

The following recommendations are made:

- There is a need to design and develop the web-App to provide health services to the patients and clients in rural areas in Kenya
- For the project's sustainability, the videoconference equipment available in MMUST should be used in practice and research-oriented teaching to facilitate learning and research activities between MMUST and THB.
- The use of practice – and research-oriented teaching need to be encouraged in other schools in MMUST to foster interdisciplinary and multidisciplinary research.
- There should be close integration of science in the educational process to promote scientific work, and the results will be of significant impact on society.
- Establishing virtual learning settings and centers and developing interactive videos for use in teaching practical and clinical skills is recommended to facilitate learning and acquisition of skills for competence during practice.

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Practice-orientated University Education in Western Kenya: The Development of a Comparative Balance Study Germany-Kenya

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Abstract: The article describes the development of a study in multidisciplinary teaching and learning. The aim is to generate balance data sets from students from different universities. Students' use of simple sensors and software development will help to analyze this data. It will involve student teams from three disciplines: health, computer science, and medical informatics. The data sets will be made available to public data for other studies. The experiment results will present an opportunity of using inexpensive, flexible, and meaningful resolutions to assist in evaluating and monitoring activities, further a platform for students to learn through practice-oriented teaching.

Keywords: Collaboration, Education, Research, Static and Dynamic Balance, Statistical Analysis.

Introduction

The German Academic Exchange Service has been supporting the project ProUniEdu-WeK (Practice-oriented University Education in Western Kenya) since 2017. The aim is to promote practice-oriented teaching to prepare students better for the job market. In the project, the Masinde Muliro University of Science and Technology, the Brandenburg University of Applied Sciences (Technische Hochschule Brandenburg – THB), the Magdeburg Stendal University of Applied Sciences, and the Eberswalde University of Sustainable Development (HNE) work together in the fields of public health, physiotherapy, technology, computer science, medical informatics, and agriculture. In this way, they create an interdisciplinary context where they work and teach together on various subprojects.

Integrating practice into teaching is a central concern of all participating partners. In the practical application of high theoretical knowledge, students acquire the necessary skills to structure problems and develop solution concepts actively. The Comparative Balance Study Germany-Kenya is such a research project enabling cooperation of three different domains: Physiotherapy, Computer Science and Medical Informatics. The partner of each domain contributes to the project:

- Physiotherapy represents the medical domain. Balance plays a vital role in accomplishing activities of daily living for all persons. Any pathophysiology is affecting body equilibrium results in complications such as falls. Hence the need

to have simple, low-cost clinical methods to analyze kinetics and kinematics of motion. However, there is a prevalence of a need for qualitative and quantitative balance data (Estévez, 2021, Moore, 2015). Thus, this study aims to generate data about balance indicators. The partner of the physiotherapy department at the MMUST contributes to this project by offering the experimental setting and conducting the experiments with students in Kakamega (Kenya).

- The Computer Science Department of MMUST is responsible for developing a web app to manage the measurement data, present the results to the patients, and implement the medical view for the physiotherapists.
- The Medical Informatics Working Group of the Department of Media and Informatics at the THB is responsible for conducting the experiments with students at their university. Furthermore, this department is responsible for analyzing and evaluating the biosignals of the experiment.

In all the departments, students are directly involved. During the pilot study, the experimental setting will be explained to the participants, and they will learn the requirements, conditions, and limitations of such experimental settings. They learn how to analyze the data and present the results to the patients (here students) and the physiotherapist keeping in mind the very different expectations of these users.

Objectives

The objectives cover two different aspects: the issues of practical oriented teaching and scientific oriented projects and the scientific balance study.

Objectives related to research and practical oriented teaching covering educational aspects:

1. Teaching the students about planning and organizing experiments for the physiotherapy domain,
2. Development of a stable experimental setting applicable in both countries,
3. Implementation of these experimental settings in two countries with very different environmental conditions,
4. Evaluation of the sensors concerning reliability and validity,
5. Analyze the experimental data,
6. Teach and train the students how to use measurement devices and collect data,
7. Development of the statistical analysis strategy, and
8. Design and implementation of an application for data management and data presentation for different user categories (patients, students, physiotherapists)

Objectives related to the evaluation of balance

1. To assess the static and dynamic balance of subjects standing on a firm platform, a balance board, and a small beam
2. To determine if there are any interactions when subjects stand on a firm platform, a balance board, and a small beam
3. To evaluate and compare the data of the two cohorts with students of the same age but from different countries/continents.

Baseline measures for persons with no pathology permit the formulation of standard referencing data. However, the variability of data related to human balance has changed even within individuals. Hence, the need for a vast amount of data to compare changes due to pathologies and improve performance.

This study aims to collect a data set on static and dynamic balance by using wearable motion sensors of subjects standing on a firm platform, a balance board, and a small beam and data used in ICT applications.

System and Experiments

One goal of the comparative balance study is to create a data set of quantitative and qualitative evaluations related to the human balance of young adults. The subject's balance will be evaluated by balance tests using a firm platform, a balance board, and a small beam. The subject's movement during the tests is measured using three smart and wearable sensors and the free available software from mbientlab (mbientlab.com). In addition, the subjects will be interviewed to collect information about their anatomical and fitness characteristics. Short cognitive and balance tests will be employed.

Cohorts, subjects

The balance study primarily addresses many health students in Kenya (Kakamega) and Germany (Brandenburg upon Havel) and, secondary, to other healthy or sick persons or patients. This study aims to find about 50 volunteers in both countries to participate. All participants will be asked to provide informed consent about the experiments, data storage, and the future use of data prior to study participation. The study will be approved by the local ethics committees.

Sensors and Software

The bright and wearable MetaMotionC (MMC) from mbientlab offers real-time and continuous monitoring of motion, logging sensor data on-board (flash memory of 1 MByte). On-board sensors include a triple-axis gyroscope, accelerometer, magnetometer, and a sensor fusion providing, e.g., quaternions, linear accelerations, and gravity with an update rate of 100 Hz. MMC sensors are part of Inertial measurement Units (IMUs) that have been applied in the context of rehabilitation tracking [Giggins, 2014, Zhang, 2020, Bevilacqua, 2018]. The measured data will be acquired using the freely available but limited software for Android-, Windows- and iOS-platforms or the App developed for this study.

Experimental Setup

Considering the desired number of participants, the time needed to evaluate one subject must be minimized. Therefore, the number of used sensors is reduced to three because of the long download of logged sensor data. They are applied to both legs above the ankle using sleeves and one in the middle of the back using a belt clip. The sensors will be grouped and synchronized. They will be configured in two variants: first, to acquire sensor data from the accelerometer (100 Hz), gyroscope (100 Hz), and magnetometer (25

Hz). Second, log sensor fusion results (quaternion and linear acceleration) with an update rate of 100 Hz.

The experiment is planned to consist of three basic exercises:

1. to stand for 60 s as still as possible on a firm platform (45cm x 45cm) with open and closed eyes,
2. to balance for 20 s as still as possible on a balance board (47cm x 37cm), and,
3. to move forward and return on a balance beam (360 cm long, 10 cm width, 35 cm height).

Procedure

All exercises will be executed three times each in the following sequence:

1. Interviews and preliminary tests,
2. Application, configuration, and the start of the sensors,
3. Move to the balance board and try to balance on it for 20 s,
4. Move to the balance beam, balance forward, and return,
5. Move to the firm platform, stand as still as possible with open eyes, leave the platform and relax for 30 s, stand as still as possible on the platform with closed eyes,
6. Repeat 2 – 5 two times.
7. Remove sensors, download and store the sensor data.

Immediately before and after each exercise, the subjects are asked to raise their left leg to get a trigger event in the signal. The whole procedure (without downloads) requires about 15 minutes.

Sensory evaluation

Students of the THB evaluated the IMC's concerning the validity and reliability of measured data. They used XSence (<https://www.xsens.com/>) sensors as the gold standard and compared the measured results from both sensors for the same experimental setting.

Data Processing

Data processing and evaluation must be automatically proceeded due to many data sets. The needed data processing algorithms will be developed in parallel with the experiments. At the first step, the signal will be split into sequences related to a single exercise (balance board, beam forward, beam return, platform open eyes, platform closed eyes). In the second step, the signals are processed, considering the time and frequency domain signals. Finally, various features like the execution time, statistical parameters of the signals, power consumption, or frequency characteristics are determined and collected.

Data Evaluation

The data evaluation consists of three phases. First, the two separated cohorts (students from Kenya and Germany) are evaluated, i.e., statistical analysis is done, good, sufficient, and lousy balance indicators are identified, and the correspondent groups are compared. Second, the data and the results of both cohorts are compared. Are there essential

differences between them? Third, the overall results will be investigated to identify an indicator to quantify the level of balance, e.g., for patients during treatments or recovery.

Technology Description

This study aims to develop a Human Activity Recognition (HAR) application enabling a standardized balance assessment. Many studies have used HAR applications to collect data in developing activity recognition systems (De-la-hoz-franco, 2020, Valarezo, 2017, Recognition, 2019, Loose, 2020). The HAR application will investigate balance activities within a controlled setting. The application would be designed and developed using Mbientlab's open API (mbientlab.com). A custom software solution is needed that would be able to connect to 3 devices. This will be implemented using a program running on the control computer with multiple BL dongles. Each dongle could be connected to 1-2 MMCs, ensuring that the connection is within the recommended specifications. Using the API, it is also possible to alter the sampling frequency of each sensor within each device. So, if there are 2 MMCs connected to one BL dongle, then each device can use half the bandwidth during streaming. The study will determine the validity and reliability of the application by (Estévez, 2021) comparing the two data sets from the two cohorts and (Moore, 2015) determining the test-retest reliability of application-derived balance times within both laboratory settings.

Conclusion

The concept actualization of this study will take place in different trimesters. To enable students to experience multidisciplinary learning as they meet the study's objectives and the curriculum. Multidisciplinary learning offers the opportunity to students in various disciplines to bring their expertise in tackling tasks. By providing the opportunity to undertake this study, a project-based learning experience, the learners are challenged to solve a real-life issue. This is through the innovation challenges related to health. Consequently, the health worker student has increased awareness of how collaboration with other disciples can offer cost-effective solutions to meet patient needs. The ICT students appreciate user needs and the significance of the difficulties when tackling complex challenges.

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Rural Healthcare Transformation through the Use of a Telemedicine Diagnostic Toolkit

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Abstract

Globally, rural communities face barriers when accessing health services. Significant challenges in providing health services in rural settings include limited communication systems, infrastructure, and transportation, leading to shortages of health professionals since they prefer urban setups with more amenities. Further, rural settings have restricted access to resources for diagnostics, prevention, and curative purposes. The project aimed to develop an IoT-based diagnostic tool kit to help capture data from community members remotely, anchored on information and communications technology (ICT), process and store, then transmit to a higher-level facility. A series of participatory design workshops and virtual meetings were conducted between the MMUST team, Brandenburg team, and a few identified stakeholders of the communities involved. The participatory approach and the virtual meetings aided the stakeholders in interrogating the developer's design, thus infusing practical ideas into the development, thereby owning the process. Therefore, the project is seen as handy and timely to support the vision of UHC. It is also worth noting that the unique needs should inform the health innovations of the end-users and potential beneficiaries. The project appropriately embraced this and thus involved all the key stakeholders at all the stages of development. The project also took cognizance of the previous studies that have assessed rural health professionals' perceptions regarding the specific needs to improve health services in their settings. This included the point of care equipment for diagnosis and therapeutics, information and communication technology, and training needs to overcome clinical problems and socio-cultural issues. Addressing primary health concerns and gathering data at the community level will plug into national surveillance, thus guiding proper decision making and scale-up; hence, aid transforms rural healthcare.

Keywords: Telemedicine, Rural Community, Diagnostic Toolkit, IoT

Introduction

Globally, rural communities face barriers when accessing health services (Foutz 2017, Moy 2017). Significant challenges in providing health services in rural settings include limited communication systems, infrastructure, and transportation. This leads to shortages of health professionals since they tend to prefer an urban setup with more amenities. Further, there is restricted access to resources for diagnostics, prevention, and curative

purposes (Moy 2017). In response, numerous initiatives have focused on fostering technological innovations, new management approaches, and health policies. Notably, in the recent past, numerous initiatives have tried to take advantage of digital health to address some of these significant challenges by developing and implementing technological innovations such as telemedicine, telehealth, and m-health. In addition, other innovations to obtain more effective and equitable health systems have also been advocated for, including new management approaches and changes to health policies [3]. Digital health is the application of information technologies and the data they generate to support engagement and informed decision-making by individuals, health providers, and health systems to increase health and wellness for all (USAID 2020).

The project took advantage of the collaboration between Masinde Muliro University of Science and Technology and the Brandenburg University of Applied Sciences (Technische Hochschule Brandenburg – THB). The German Academic Exchange Service has supported this collaboration. The project sought to utilize digital health by leveraging eHealth and IoT technologies.

EHealth has been defined as the "use of information and communications technologies (ICTs) in support of health and health-related fields, including healthcare services, health surveillance, health literature, and health education, knowledge and research" (USAID 2020). In contrast, IoT allows patients to be monitored, or their data be taken remotely utilizing networks of medical devices equipped with sensors and actuators that collect healthcare data from patients and send them to a cloud-based Hospital Information System (HIS) for analysis and interpretation. A prototype of the product from these technologies has been developed and tested. The focus is to use community health workers (CHW) to help collect patient data. They are crucial to achieving universal health coverage (UHC) by 2030, a Sustainable Development Goals (SDGs) target (WHO 2010).

The project aimed to develop an IoT-based diagnostic tool kit to help capture data from community members remotely, anchored on information and communications technology (ICT), process and store, then transmit to a higher-level facility. Thereby assisting the Ministry of Health (MOH) and health program managers at national and sub-national levels to effectively assess, plan and address their health and wellbeing. The telemedicine Diagnostic Toolkit was aimed to have the following capabilities:

- Capture patients' essential details using IoT Sensors
- Display the patient data into client applications (mobile apps, web dashboard, and other display software)
- Transmit the captured data to a remote database server
- Coordinate communication and data sync in all available software

Methodology

A series of participatory design workshops and virtual meetings were conducted between the MMUST team, Brandenburg team, and a few identified stakeholders of the communities involved. Participatory design (PD) is a methodology that promotes users' participation in the design process of technological solutions. Therefore, it can design

technologies that more closely align with the users' needs. PD in telehealth was an iterative process clarifying user needs, possible solutions, and pragmatic trials involving the participants. The developers applied a Design Thinking methodology, which provided a solution-based undertaking, to solving problems. It helped tackle complex problems that were ill-defined or unknown by understanding the human needs involved, re-framing the problem in human-centric ways, creating many ideas in brainstorming sessions, and adopting a hands-on approach in prototyping and testing. It adopted the five stages of Design Thinking (empathize, define, ideate, prototype, and test). The participatory approach and the virtual meetings further aided the stakeholders to interrogate the design and infuse practical ideas into the development, thereby owning the process.

Results

At the end of the design thinking process, different results are the input for the developmental process:

1. Main aims and success criteria of the project:
 - Tools that assist in information gathering
 - Tools that facilitate diagnostic collaboration, particularly with specialists
 - Systems that facilitate feedback and insight into the diagnostic performance
 - Quality captured data and secured transmission of the same.
2. Persona describes the specific requirements of the different users:
 - Physicians: Medical personnel responsible for taking care of patients through the analysis, diagnosis, and treatment of diseases. They can be typically general or specialist medical practitioners focused on specific disease categories and treatment methods.
 - Operators: Medical personnel responsible for visiting (periodically or on-demand) patients at home and forwarding information to physicians if a risk is detected. They represent the direct link between patients and the hospital/caregiver services.
 - Patients: People on whom the device will be used to collect data or who need a long time convalescence. Their biological activities, habits, and environmental factors are continually monitored to give medical personnel updated information on their health status.
 - Community Health Worker (CHW): The CHW's play an essential role in health management in rural areas. They have a simple basic medical education and can go from house to house to record data from the patients. They represent the interface to the medical service of a hospital.

- **Systems Administrator:** The system administrators are responsible for data management, data distribution, and user administration.

After identifying stakeholders, the user requirements a general model for data communication and transmission describes the data life cycle in the telemedicine setting (figure 1).

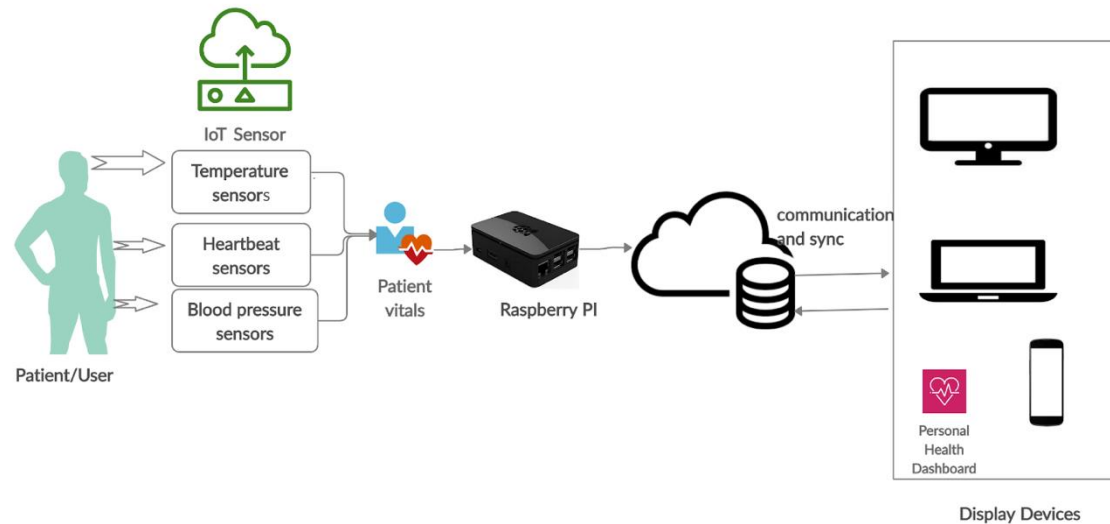


Figure 47: General, abstract system model for the telemedicine kit

The processing of the following design steps led to a design of an adapted IoT system architecture concerning the requirements of the telemedicine setting:

- The functional analysis describes what the system does and identifies all the system's functions to meet the operational requirements.
- Technology investigation describes how the system works and identifies possible technologies practical to implement the sub-functions in the system.
- Service and software development - it included the effort in developing new services and software components that are specifically designed for the project.
- Integration—it provided an abstract definition of the system to capture the key processes, data relationships, and data sources necessary to the whole system.

The 4 Stage IoT Solutions Architecture

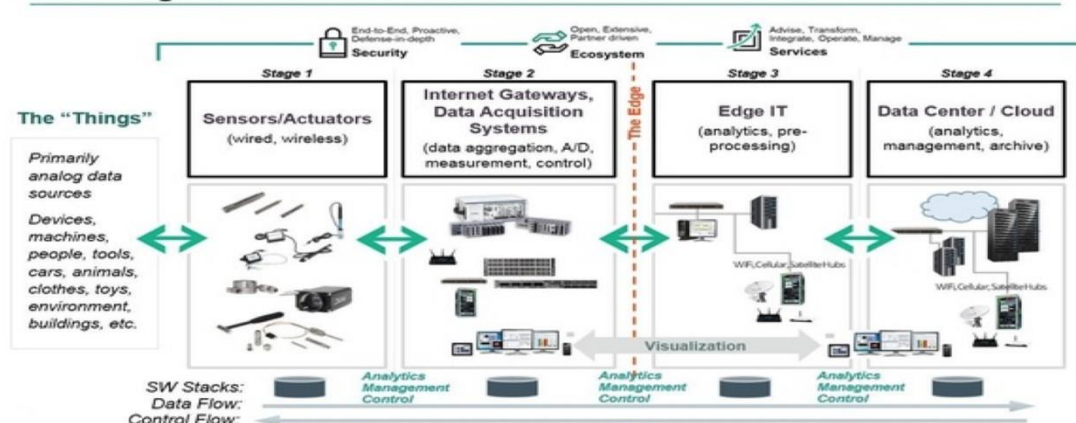


Figure 48: A Four-Stage IoT Solutions Architecture for the Telemedicine Diagnostic Toolkit

Discussion

Recognizing that inclusive growth, sustainable economic development, national health security are essential policies, objectives that cannot be achieved without a healthy population. Almost all countries globally, irrespective of their level of development, have embraced universal health coverage as a pathway to greater national prosperity (WHO 2011). Globally, Information and Communication Technology (ICT) has emerged as a critical enabling tool to help achieve effective monitoring and management of service delivery (Krummel 2009). ICT can produce real-time information for fast decision-making and appropriate action. Therefore, this project is seen as handy and timely to support the vision of UHC. It is also worth noting that the unique needs should inform the health innovations of the end-users and potential beneficiaries. The project appropriately embraced this and thus involved all the key stakeholders at all the stages of development. The project thus took cognizance of the previous studies, which have assessed the perceptions of rural health professionals regarding the specific needs to improve health services in their settings. Including the points of care equipment for diagnosis and therapeutics, information and communication technology, and training needs to overcome clinical problems and socio-cultural issues.

Further, addressing primary health concerns and gathering data at the community level will plug into national surveillance, thus guiding proper decision-making and scale-up. Telemedicine is a type of ICT that will move treatment and monitoring of patients away from hospitals and to the familiar surroundings of the patients' own homes or alternative treatment offers (Strasser 2003). Telemedicine applications are believed to make it possible to provide healthcare in new and more efficient ways and are seen as one of the keys that open the door to the health services of the future (UN 2009). By preventing acute deterioration in patients' condition and reducing the number of admissions to the hospital, a higher quality of treatment and a better quality of life for the patients can be provided.

The application of IoT technology to telemedicine offers an appropriate setting for continuous monitoring of patients (Albahri 2021). However, in this specific set of CHW in rural areas, continuous monitoring is not the primary aim but the ubiquitous availability of innovative technology.

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A Review on the essence of Health Communication on Chronic Illnesses among Rural Population during the Covid-19 Period

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Abstract

Diabetes, cancer, chronic respiratory illnesses, and cardiovascular diseases jointly contribute up to 63% of deaths globally. The highlighted diseases are affecting the rural population more than urban populations. This is attributed to low levels of awareness among the rural populations. With the outbreak of COVID-19, the lives of those living with chronic illnesses are at high risk of contracting the disease and even dying. This paper presents the need to employ health communication strategies to increase knowledge and awareness to attain improved health resulting to low effects of COVID-19 on those living with chronic illnesses among rural populations.

Keywords: Health Communication, Rural Populations, Communication Strategies, Chronic Illnesses, COVID-19

Background

According to International Diabetes Federation (2017), diabetes, cancer, chronic respiratory illnesses, and cardiovascular diseases jointly contribute up to 63% of deaths globally. 80% of the said deaths occur in low and middle-income countries (WHO, 2013b). In Kenya, as of 2017, one death is reported for diabetes after every 8 seconds. The rate is expected to rise from the current 3.3% to 4.5% by 2025 (Jones, n. d). Similarly, Tuberculosis (TB), a chronic respiratory problem, reports 426 cases for every 100,000 persons (Enos et al., 2016). In addition, for cancer, the caseload is on the rise, whereby 48,887 cases were reported in 2018 from 37,000 cases in 2012 (Kenya Cancer policy 2019-2030).

The COVID-19 pandemic poses a threat to the gains that have been made in addressing these diseases. A global TB report by WHO released in 2020 indicates that deaths resulting from TB are likely to increase from 0.2 million to 0.4 million by 2025 if health services continue being disrupted due to COVID-19. In addition, COVID-19 poses a greater threat to those who have diabetes. When they develop the virus, it can be harder to treat them due to fluctuation in blood glucose levels and the possibility of glucose complications (International diabetes federation, 2021).

The highlighted diseases are affecting rural populations as compared to urban populations. This is attributed to low levels of awareness among the rural populations on the said diseases. For instance, the level of awareness on diabetes is rated at 48.6% in the urban setups as compared to 39.5% in the rural areas (Mohamed et al., 2018). The Institute

of Medicine of the National Academies (2002) concurs that the burden of death and disease frequently and heavily affects those with low education and income levels. According to Hendricks et al. (2012), 83% of people suffering from chronic illnesses in rural Kenya are unaware of their condition and thus fail to seek medical attention. This depicts that rural communities need communication campaigns on health issues to create awareness and prevent diseases.

The Kenya National Diabetes Strategy 2010-2015 advocates for increased education among target populations through multiple communication channels such as community groups, schools, workplaces, mass media, religious organizations, and health centers. According to Freiberg et al. (2016), a multifunctional approach is needed to address the state of chronic illnesses to improve access to health care services and improve levels of health education. The Kenya National Strategy for Prevention and Control of Non-communicable diseases 2015- 2020 advocates for joint communication efforts involving politicians, media, health professionals, and the community for social change towards prevention and control of these diseases. This would involve sharing messages that address chronic illnesses in Kenya through multiple communication platforms. Hence, the need for health communication.

What is health communication and its benefits?

Health communication is one of the fast-growing areas of communication (Feeley and Chen, 2013). According to Thomas (2006), health communication involves studying and using communication strategies to inform and influence individuals and a community regarding knowledge, attitude, and practices related to health and healthcare. Schavio (2007) agrees that health communication targets individuals and communities to whom health-related information is shared to improve health outcomes. Health communication aims are to influence both individuals and communities.

Thus, health communication targets both individuals and members of a targeted region, known as community members, with health-related messages to influence and change behavior to attain desirable health behavior. Health communication focuses on a more extensive scope ranging from aspects of disease control, health promotion, health care policy, and the business of healthcare (ibid, 2013). While it can be argued that experts in the health sector should handle health communication, scholars have noted that health communication is multidisciplinary. Uzagare and Kumbhar (2017) argue that health communication on diabetes, and this can apply to all other chronic illnesses, can best be handled by a multidisciplinary team for a significant impact. This agrees with Schavio (2007), who confirms that health communication draws from numerous disciplines such as health education, mass and speech communication, marketing, among many others.

Health communication has been noted to have achieved impressive results as far as dealing with chronic illnesses. According to Uzagare and Kumbhar (2017), health communication has reduced issues arising from diabetes, such as foot ulceration, amputation among others. They further state that health communication is a foundation of a preventive care system. This implies that chronic illnesses can be easily controlled by running a communication program.

According to Kourakos et al. (2017), in tackling chronic illnesses, patients and families are no longer passive recipients of services but must actively participate in effective communication alongside clinicians. However, the quality of communication among the parties concerned determines how the messages will be received and acted upon. According to White et al. (2015), the quality of communication may be an essential modification approach to improving diabetes care for the vulnerable population. This, in turn, will improve the knowledge gained on diabetes hence reducing the risk.

While the quality of communication that can transcend behavior changes remains unknown, Alsayah et al. (2013) observes that low health literacy on diabetes is one of the key barriers to adequate care due to lack of adherence to medication and poor glycemic control. Uzagare and Kumbhar (2017) concur that some patients fail to use the medicines that they receive from doctors due to lack of awareness and lack of proper communication at the grassroots level leading to underutilization of the services by patients. This further reveals that effective communication has the power to influence public health (The Institute of Medicine of the National Academies, 2002). The institute further notes that communication on health can tackle behavioral, normative, and even control beliefs that underlie attitudes that are perceived norms among the targets. This can be done through sharing well-designed messages that can change one or more well-defined behavior.

Methodology

This paper employed a literature review on articles that focused on the state of chronic illnesses in Kenya to gather evidence on the application of health communication in addressing these diseases and enhancing support for health-related behavior.

Results

Most articles reviewed showed the need for incorporating health communication in health education programs to increase awareness of chronic illnesses among rural populations. According to a study conducted by Rachilis et al. (2016) on the common barriers and facilitators to linkage and retention in chronic disease care in Western Kenya, lack of knowledge and understanding among patients on the need to link affects care given to those living with chronic illnesses. Further, patients lack knowledge on the need to continue taking drugs even when their health is not improving, leading to most patients' termination of drug use. Another study conducted in Nyeri, Kenya, on the knowledge and perceptions on chronic diseases in Kenya shows that there are many misconceptions about chronic illnesses in Nyeri. The study recommends educational programs to provide knowledge deficiencies (Freiberg et al., 2016).

Poor knowledge is a crucial hindrance to health care given to those suffering from chronic illnesses in Kenya. A study conducted by Kimani et al. (2018) on the needs of patients living and dying with heart failure in Kenya revealed that most patients lacked information on the nature of their illness, self-care, and lifestyle changes to prevent heart diseases. The study also noted that most patients who sought treatment had acute conditions, whereas those with gradual symptoms did not see the need to seek medication. A study on knowledge, attitude, and practices related to diabetes conducted in four regions in Kenya also showed high levels of poor knowledge on diabetes rated at 73 % (

Maina et al., 2011). This problem also affects cancer patients, with approximately 35% of the rural population have not having heard of cervical cancer leave alone going for cancer screening (Gatune, 2005).)

The knowledge levels on chronic diseases can be tackled by employing health communication campaigns. According to an article released on September 25, 2020, by Tulane University on ten strategies for effective health communication, health communication can enlighten people by increasing awareness on a health problem and describing healthy skills to demonstrate the benefits of adopting new health behavior. For instance, a health communication campaign conducted by the Center for Disease Control and Prevention featuring real stories of people living with smoking-related diseases prompted many to quit smoking. This shows that health communication needs to use more than one approach to realize the desired effects. According to a general report by the European Union on the study on communication to address and prevent chronic illnesses released in 2015, health communication should employ combined interventions to achieve more effects to bring about sufficient widespread behavior. To concur, Otieno (2008) says that interpersonal communication should be integrated alongside other communication channels to increase the efficiency of a health communication exercise. Freiberg et al. (2016) emphasize that community health workers should be an entry into communities and, in particular, to those living with chronic illnesses because they understand the local language, culture, and people and thus are in an excellent position to enact change.

Conclusion

In summary, chronic illnesses will continue posing a great danger to rural populations in Kenya due to low levels of knowledge and awareness created on these diseases. With the existence of various variants of COVID-19, the lives of those living with chronic illnesses are threatened. However, health communication can provide a solution by increasing knowledge levels among rural populations. Health communication programs should target rural dwellers to fill the existing gap in terms of lack of knowledge on some of the critical illnesses, which has continued to affect both disease prevention efforts and management and cure activities. Various channels of communication, integrating both the mass media and interpersonal channels, should be utilized in health communication campaigns to realize better results. Health communication is inevitable to impart knowledge and change attitude on chronic illnesses and many other diseases.

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Digitalization and Collaboration in Mathematics & Science Education (DICOMSE) – a ProUniEdu-WeK II Project

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Abstract

The immediate, global impacts of the coronavirus pandemic (COVID-19) on teaching and learning in higher education are well documented in the literature. Focusing on student and faculty experiences of online and distance education, this paper provides reflections on initiatives, unexpected challenges, and lessons learned since the attack of the COVID-19 pandemic started. There was an urgent need better to understand online teaching and learning during the COVID-19 pandemic. Both students and faculty members in higher education institutions were taken by surprise. The paradigm shift from face-to-face to online teaching took its toll on institutions. This paper will share a case study of Masinde Muliro University of Science and Technology (MMUST). This includes lived experiences of both students and faculty members. It will underscore how the use of information and communication technologies (ICT) impacted students, faculty, and staff experiences during the COVID-19 lockdown. Challenges faced by universities and educators in their attempts to overcome the practical difficulties involved in developing effective online programs and pedagogy will be discussed. Issues of socio-economic status and inequality will be articulated. This paper will support further discussion on the effect of the pandemic on partnerships and collaborations. Finally, the big question to confront is based on our experiences and lessons learned, how do we ‘go online’ in ways that provide effectively and quality education for all?

Keywords: Digitalisation, Higher Education, COVID-19 Pandemic, Pedagogy

1. Introduction

Given the limitations caused by the COVID-19 pandemic in the world, DAAD funded seven sub-award projects as part of the practice-oriented University Education in Western Kenya II project until August 31st, 2021, to support digitalization measures serving the general grant purpose. Examples for digitalization measures, according to DAAD guidelines for Subaward Agreements of 2020, were:

- Coordination and working meetings via virtual channels (e.g., video conferencing)
- Implementation of virtual events (e.g., webinars)
- Participation in digital study programs (e.g., online courses) and exchange formats (e.g., virtual classrooms)
- Development of digital teaching and learning materials (e.g., new online modules and extended use of available Learning Management System (MLS) capabilities)

- Accompanying measures for digital adaptation such as technical and organizational measures (e.g., linking of learning infrastructures via interfaces)

2. Implementation of the DICOMSE Project

This project integrated technology in pedagogy at the university teaching a statistics course to two doctoral students in the mathematics education department. The course lecturer, Dr. Aurah, collaborated with Prof. Dietmar Wikarski and Prof. Peter Flassig (from Brandenburg University of Applied Sciences) to convert the course *ESM 913: Advance Application of Statistics in Educational Research* into an online form and co-taught through Moodle as LMS, SINGH (2017) or SILVA (2017). Through this project, the following goals were achieved.

1. The lecturer designed an online course for *ESM 913: Advanced Application of Statistics in Educational Research*
2. Ability to conduct online teaching on an LMS platform using the Moodle software and the virtual conferencing tool BigBlueButton (BBB), which is available as a Moodle plugin. During the project, the following plugins were used: assignment, BBB, book, chat, feedback, file, folder, forum, interactive content, lesson, and quiz (see Appendix I). An account set up for MMUST LMS for the BUAS team to allow efficient and active collaboration,
3. Collaborative teaching of the course: Dr. Catherine Aurah collaborated with Prof. Dietmar Wikarski and Prof. Peter Flassig of BUAS to teach the course (see Appendix E). During that time, Prof. Flassig shared his experience of online course development.
4. More than ten virtual meetings between MMUST and BUAS to share, teach, discuss and train the use of Moodle as LMS, and for teamwork as well,
5. students had the experience of navigating the LMS and having chats virtually.
6. Participants explored and used Moodle activities (plugins) such as a forum, books, URL, feedback, page, and BBB (see appendices E, F & G),
7. BBB was used as an alternative for ZOOM with the following advantages:
 - a. saving of financial resources (for future, MMUST does not need to request or allocate budget for ZOOM because BBB provides all required capabilities) and
 - b. enables MMUST students to collaborate time-independent and self-organized virtual without additional costs.

3. Challenges and Difficulties in the Realization of the Goals and Lessons Learnt

As described by other authors such as Kraska 2020 and Rosalin et al. (2020), several challenges and difficulties were experienced during online teaching and learning. Among them were:

1. Poor internet connectivity for the students led to problems.
2. Lack of proficiency in ICT skills regarding LMS led to problems.
3. Participants' diaries were challenging to harmonize; hence scheduling meetings and classes was a challenge.

4. Students were busy in schools most of the time when the Kenya Certificate of Secondary examination was in session. The Ph.D. students are all high school teachers. They were invigilating examinations.

While running the project, lessons were learned through both successes and failures. The most important ones can be summarized as follows:

1. Online teaching and learning is a possibility that should be embraced and adopted by everyone in the teaching business. We found out that the setup of high-quality Moodle content is vital for efficient asynchronous learning. In Appendix A, a screenshot of a section of the ESM 913 course outline created and jointly taught is attached.
2. Adequate preparation is needed before implementing an online class. Such preparation includes and is not limited to internet connectivity, capacity building of the students, and even instructors on how to navigate the LMS.
3. Enough digital resources should be sourced beforehand.
4. Compatible digital devices are a requirement before starting the class.
5. Proper design of online courses is necessary to make them learner-centered and interactive.

4. Way Forward and Specific Outlook

Suggestions and strategies can be derived from the lessons learned to cope with the experienced challenges. In addition, a specific proposal of how to proceed is given below.

To manage poor internet connections which is countryside we propose to use multiple rooms at MMUST for a lecture. This will lead to fewer people in a room to account for Covid-19 restrictions and ensure a robust internet connection. Here, two further advantages would be that MMUST hardware could be utilized and that students, although in small groups, could interact vis-à-vis.

Another potential solution is a further increased use of asynchronous teaching, e.g., BBB records or quizzes in Moodle, cf. Kraska (2021) or Flassig and Kraska (2021). BBB recordings have been proven to be a powerful way for asynchronous teaching and are highly appreciated by students at BUAS. Due to this, this option should be explored next.

In the future, it is planned to explore powerful Moodle plugins further and to find out how to get new plugins, i.e., capabilities for Moodle LMS, installed at MMUST. Here, in particular, the authors think of “Tasks”, “External Tools”, “Virtual Programming”, “Live Tests”, which are present in BUAS Moodle but not at MMUST, Appendix B, C.

It takes time to get familiar with the full functionality of Moodle as LMS, to create appropriate courses, and to train students why a timeline for transition or creation of Moodle courses should be defined and time should be allocated. This will help to avoid not aligned or default courses that have been created under pressure. Properly aligned courses are essential that students will make intense use of them.

Since approximately 350 students will benefit from this sub-project, student focal needs to be trained to act as first contact and supporting points related to LMS questions. This could also increase inter-student communication under pandemic restrictions.

The success of this project is both motivating and encouraging to continue with online teaching and learning. For the future following is planned at MMUST in collaboration with BUAS:

1. Continuation using the goods purchased to teach the current students.
2. Further conversion of master courses to online modules and teaching.
3. Regular conduct of online assessments.
4. Training of the students on the use of LMS.
5. Currently, during face-to-face sessions, the projector and the laptop are used. Moving forward, the equipment will be used by faculty members from the Department of Science and Mathematics Education (SME) and the school of education (SEDU). The author Dr. Aurah will use it when teaching undergraduate students: ESM 410: Environmental Education; ESM 412: Contemporary Issues Science, Technology and Society. Of much interest is ESM 412, where the impact of technology on education as one of the topics is learned. CIT399: Microteaching Component: Students can prepare PowerPoint presentations and peer teaching
6. From the previous paragraph, it is forecasted that more than 350 students will benefit from this project.

Besides a strong collaboration, online teaching and learning require hardware and software, particularly if the number of users, i.e., teachers and students, is increased by more than a magnitude, e.g., from ten to 350. Therefore, one should not forget the purchase of additional state-of-the-art hardware and software, e.g., additional Moodle plugins, if work on digitalization of teaching at MMUST is further deployed, disseminated, and continued.

As a final motivating and encouraging notice, MMUST and BUAS agreed on a future collaboration of eight science and mathematics education lecturers at MMUST and counterpart faculty at BUAS with the following two specific objectives:

1. Conduct baseline surveys on the preparedness of lecturers and students at MMUST to digitalize teaching and learning.
2. Design and schedule professional development according to mentioned aspects for the lecturers related to online teaching and learning.

Appendices

Appendix A: Snapshots of the course ESM913: Advance Application of Statistics in Educational Research illustrating the status of the Moodle course that has been collaboratively developed and used as an online teaching backbone for the course during the project phase. As can be seen, BBB sessions are available for virtual communication, and feedbacks have been created and sections with specific material for individual topics of the course.

MMUST Website About MMUST ODEL ODEL Programmes Student Portal

ESM 913: Advanced Application of Statistics In Educational Research

Home / My courses / ESM 913 [Turn editing on](#)

Your progress ?

General

University: Masinde Muliro University of Science and Technology

Course Code: ESM 913

Course Title: Advanced Application of Statistics in Educational Research

Course Developers: DR. CATHERINE AURAH

Course Facilitators: DR. CATHERINE AURAH

1. Field, A. P., & Field, A. P. (2018). Discovering statistics using IBM SPSS statistics.	<input type="checkbox"/>
2. Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2019). Using multivariate statistics.	<input type="checkbox"/>
3. Howell, D. C. (2013). Statistical methods for psychology.	<input type="checkbox"/>
The Standard Normal Distribution	<input type="checkbox"/>
Hypothesis Testing Video	<input type="checkbox"/>
Parametric and Non-Parametric Tests	<input type="checkbox"/>

General

APPLICATION OF STATISTICS - BBB for Lectures	<input type="checkbox"/>
BBB FOR STUDENTS (with Moderator status)	<input type="checkbox"/>
Course Forum ESM 913	<input type="checkbox"/>
Agree on time	<input type="checkbox"/>

Topic 1

PART 1: INTRODUCTORY CONCEPTS	<input type="checkbox"/>
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Topic 3

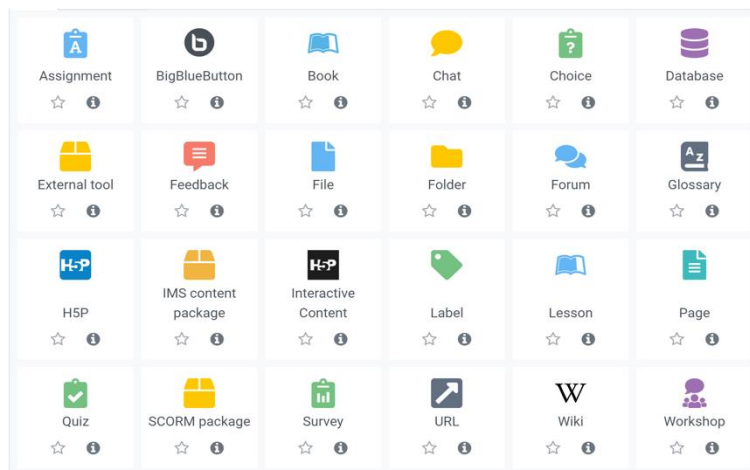
Reading Materials for Topic Two

Hypothesis testing	<input type="checkbox"/>
Hypothesis Testing	<input type="checkbox"/>

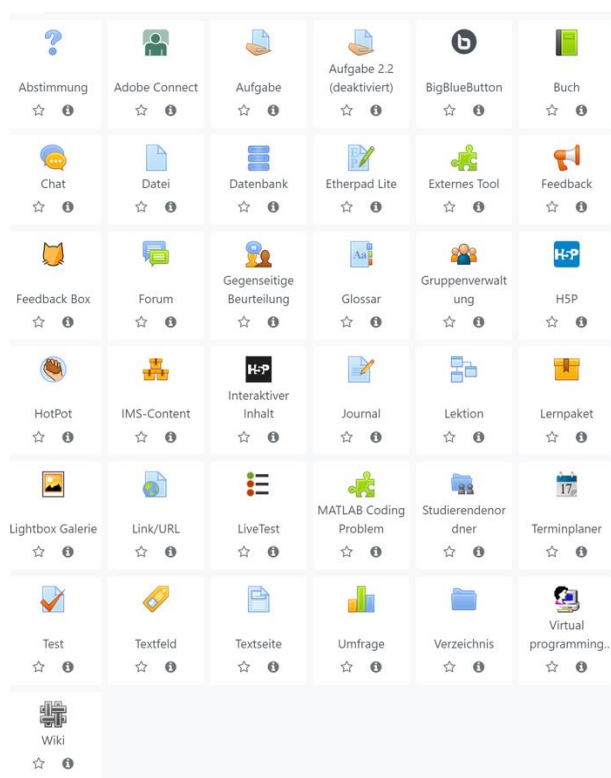
Topic 4

USING SPSS	<input type="checkbox"/>
The power-point slides introduce you to how convert data from the source to a data file using SPSS	
T-Tests using SPSS	<input type="checkbox"/>
T-Tests Using SPSS 1	<input type="checkbox"/>
REVIEW OF WORK COVERED	<input type="checkbox"/>

Appendix B: Available Plugins of MMUST Moodle at the project time. From these, BigBlueButton (BBB), chat, feedback, forum, file, or URL have been applied during the project.



Appendix C: Available Plugins of BUAS Moodle at the project time. Compared to Appendix B, it can be seen that more capabilities are available and used at BUAS.



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