ENTREPRENEURIAL TECH-ED.
Using Technology to Fuel Income Generation Education in Rural Ghana

by
Breanna Faye Rossman
Bachelor of Design in Architecture
University of Florida, 2011

SUBMITTED TO THE DEPARTMENT OF ARCHITECTURE
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARCHITECTURE
AT THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

FEBRUARY 2014
©2014 Massachusetts Institute of Technology. All rights reserved.

Signature of Author: __________________________________________________
Department of Architecture
January 16, 2014

Certified by: ________________________________
Jan Wampler
Professor of Architecture
Thesis Supervisor

Accepted by: ________________________________
Takehiko Nagakura
Chair, Department Committee on Graduate Students
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
MASTER OF ARCHITECTURE

THESIS COMMITTEE

SUPERVISOR
Jan Wampler, M.Arch
Professor of Architecture

READERS
James Wescoat, PhD
Aga Khan Professor

Sarah Williams, MCP
Ford Career Development Assistant Professor of Urban Studies and Planning

Amy Smith, MS
Founder and Co-Director of MIT D-Labs
This thesis investigates how decentralization of development occurs through merging small-scale technology hubs into the rural West African fabric by integrating with the secondary school system. This model redefines the structure of education in Ghana by establishing a programmatic fusion to create a relationship between education and entrepreneurialism. Encouraging a decentralized approach to regional development through a system of satellite tech hubs linked to secondary school campuses, the design formulates an architectural strategy that creates a platform for funding Ghanaian education.

By re-envisioning the senior secondary school as a technology and innovation research campus, the thesis becomes a site for testing new programmatic relationships within an educational environment. This includes the combination of programs such as classrooms with testing labs, a technology center that accommodates vocational training for students and community members, and an income-generating agricultural production system, in order to create a self-sustaining, entrepreneurial education system and technology-centered secondary school. This ‘tech-ed’ design prototype will act as an advocate for reform through designing the liaison between the trending multi-billion dollar tech hubs and the destitute educational system of Sub-Saharan Africa.
ACKNOWLEDGMENTS

My sincerest appreciation goes out to the faculty, staff, and entire student body at MIT for accompanying me on this journey through graduate school. It has truly felt like drinking from a firehose, and gives an infinite array of possibilities and meaning to the single most important acronym for any MIT student: IHTFP.

I would especially like to thank the following people for their efforts in supporting me throughout the past two and a half years:

To my thesis committee for helping me through the grueling process that is making a thesis. To Jan, with whom I have had the utmost pleasure of serving as ‘last MIT thesis advisee’, and for acting as both advisor and therapist throughout the last year. To Jim Wescoat, Sarah Williams and Amy Smith, for their invaluable insights and criticisms that helped contribute to my educational experience and further the development of the thesis.

To my devoted friends and colleagues who took time out of their busy schedules to offer an assortment of graphical, technical or emotional support: Lisa Cepisul, Alexis Sablone, Patrick Little, Enas Alkhudairy, Chris Mackey, Mikaila Waters, and especially Laura Schmitz, who was not only a model-builder, dinner-supplier, and ‘sprint-across-campus-to-deliver-the-last-board-mid-presentation’-er, but also a dear friend and shoulder to cry on during that pivotal moment in life when you just realize you successfully defended a master’s thesis. The presentation, book, and my amazingly intact sanity would have not been possible without the intense dedication of these individuals who so selflessly offered their time and comfort throughout the semester.

To the family that helped influence me in infinite ways: my mom, pawpaw, brothers and sisters, y mi familia Conde.

This book is dedicated to four from the above acknowledgment that never had the chance to read it:
CONTENTS

Abstract 3

I. TECH-HEAVY CONTINGENCIES 11
   Development and Migration

II. EDUCATIONAL DELINQUENCIES 19
   Networked Satellites
   Resources and Proximity

III. UNDER THE MANGO TREE 33
   Site Analyses
   DESS Re-imagined
   Agricultural Test-Beds
   Phasing and Site Development
   Material and Environmental Conditions
   D.I.Y. Construction Comic
   Physical Models

Appendix I. Funding Strategies 91
Appendix II. Thesis Defense 107
Appendix III. Initial Proposal 113
Appendix IV. Precedent Studies 121

Bibliography 129
“Architecture has to be greater than just architecture...
It has to address social values, as well as technical and aesthetical values.”

-Samuel Mockbee, Architect and Founder of Rural Studio, Auburn University
The following terms and acronyms used commonly throughout the thesis are defined as such below:

- **Digital economy:**
The recent and still largely unrealized transformation of all sectors of the economy by the computer-enabled digitization of information

- **Information economy:**
The expansion of information and knowledge based assets and value relative to the tangible assets and products associated with agriculture, mining, and manufacturing.

- **Digital divide:**
The technological gap separating communities with easily accessible use of technology and Internet from communities with low accessibility.

- **Leapfrog Technologies:**
Technologies that skip previous or all initial phasing of technological system development pre-dating the new system.

- **ICT:**
Information and Communication Technology

- **ITU:**
Telecommunication Union

- **DESS:**
Dega Senior Secondary School
I: TECH-HEAVY CONTINGENCIES
AFRICA is the fastest growing market for mobile phones.
Modern day Africa is booming. Not only is the continent the fastest growing market for mobile phone technology, but it is home to more than half of the 20 fastest growing economies in the world. Of the leading African economies, Ghana is at the forefront in economic and technological development with economic growth at 14.3% in 2011, making it the strongest-grossing country in Africa and one of the fastest-growing economies in the world. 

Despite the economic growth, development is limited to the southern region near the capital city of Accra, causing severe urban migration of impoverished rural Ghanaians seeking employment opportunities. Hope City, a $10 billion project currently breaking ground near Accra, contributes to this centralized economic approach that only encourages southern migration and prevents nationally distributed development, especially concerning employment and education. Education enrollment rates across Ghana are drastically low, with senior secondary school enrollment as low as 11% in select regions.

Africa is currently the fastest growing market for mobile phones, with the number of mobile phone subscriptions increasing from 16 million to half a billion in just one decade. This exponential increase in the telecommunications market is allowing many African countries to leapfrog decades of technologies that developed countries have endured. The first submarine communications cable linking Africa and Europe was established in 2002, and in the last decade the amount of cable connections and available bandwidth has vastly increased. The figure to the left shows the development of submarine communications cables across the continent from 2002 to 2012.

---

The five main ICT companies in Africa, with corresponding maps showing the countries they provide service for. Ghana is serviced by all five major companies.

The inclusion of technology as an international agenda for global poverty has the ability to provide easily accessible forms of education, skills, resources, and healthcare to rural populations that lack those resources. “Technology is not only access to the Internet – it is a micro-finance, health, communication and educational tool; moreover, it provides marginalized people living in slums a way to tell, document and share their stories with others.”¹ Not only does technology provide otherwise unattainable resources to residents of rural areas, but these types of low-income communities also have an advantage over more affluent populations when it comes to technology: while highly developed areas must continually upgrade the technological systems and infrastructures already established, technologically undeveloped communities can ‘leapfrog’ outdated systems, avoiding the hassle of retrofitting the new system as well as replacing the old, saving time and resources and making entire installation process more cost-effective.²

Rural villages experience many barriers in language, education, and infrastructure, making them susceptible to underdevelopment in the informational and digital economy. The sheer fact that there are little resources available allowing ‘leapfrog’ progress makes them the ideal target for intervention. This makes them an ideal target for ICT (information and communication technology) development to occur.

The map above depicts the African continent, highlighting the leading countries in providing wireless broadband service. Five of the eight are listed as having the top mobile phone users in the continent, with Ghana being a part of every category. This is representational of Ghana at the forefront of technology in Africa. Nigeria, Ghana, and Kenya are three African countries that are proposing technology hub cities costing billions of US dollars, each strategically planned within 60 kilometers to the capital. These multi-billion dollar cities are trending across developing countries, however they only encourage a centralized approach to development and lead to benefit the small, elite few while neglecting the basic needs of the population.¹ Hope City is a city that gives hope to very few, and creates a community that is socially and economically remote from the rest of the population of Ghana.

In early 2013, Ghanaian president John Mahama launched Hope City, a “$10 billion high-tech hub aiming to foster technological growth and attract major players in the global ICT industry to the West African country.” This newfound technological development has also created a new architectural typology for Accra and other leading African cities: a universal architecture that does not reflect the region. With development occurring in southern region of Ghana, the rest of the nation struggles with the lack of educational and vocational resources, low literacy rates, extreme poverty, and high unemployment. Rural areas are especially prone to stagnant development, where infrastructures and resources make education challenging, lacking, or non-existent for children living in remote villages. This thesis investigates the possibility of an intermediate architecture that acts as a liaison between small rural schools and large, urban tech-hubs.

Image (bottom right): Accra’s Hope City juxtaposed next to the neglected Dega Senior Secondary School of Ghana’s failing education system, visually representing the thesis addressing how to create a liaison between the two dichotomous systems.
II: EDUCATIONAL DELINQUENCY

Dichotomy between the high costs of education and low enrollment rates for students
Currently in Ghana, 85% of governmental funding for education is spent only on teachers' wages, leaving only 10% for materials, supplies, and financial aid for student fees. Secondary school students are met with challenges in order to even attend school, as many families cannot afford to pay the expensive student fees and costs of uniforms, books, and sometimes necessary dormitory expenses for those attending school in the closest village available.

Secondary school (the equivalent to high school) students are met with challenges in order to attend school, as many families cannot afford to pay the expensive student fees and costs of uniforms, books, and sometimes necessary dormitory expenses for those attending school in the closest village available. With scarce funding and governmental support, quality of education in Ghana struggles to meet goals of necessary improvement.

In rural areas of Ghana, schools are very scarce, limiting the option for children to attend school unless they move to another village that has a school, often relying on the help of distant relatives and adding the extra financial burden. Students are often responsible for their own living expenses, including clothes, mandatory school uniforms, eating, school fees, supplies, and books.

Currently in Brong-Ahafo, the second-largest state in Ghana, 11.2% students attend Senior Secondary School, and only 1.3% students move on to pursue further education through tertiary institutions or universities.1 Given that further education at the post-secondary level is often necessary to attain governmental, industrial, and academic jobs, there is a vast population of young people who are not able to find employment opportunities in these areas after graduation.

---

This series of maps of Ghana show the relationship between technology and education. Starting with the density of major telecommunication locations, and progressing to include coverage zones overlaid with secondary schools that have telecommunications facilities integrated within the campus.

A visual representation of the dichotomous relationship between the northern and southern regions of Ghana, the lack of technological and educational development in the north is evident by the last map showing the four major “gap zones”. These four zones are the targeted regions for proposed development of tech-education secondary schools to merge with technology hubs in order to create a more decentralized national development.

Images (right):
Map of Ghana locating senior secondary schools targeted for a technical school focus, with darkened brown areas marking zones where technical senior secondary education is non-existent in the particular surrounding regions.
Senior Secondary Schools targeted for Telecommunication Facilities and Mobile Phone Coverage Zones

Predicted Mobile Phone Line Extension and Coverage Growth

Targeted “Gap” Coverage Zones for Implementation

KEY:
- Senior Secondary Schools
- Fixed Lines
- Telephone Exchange
- Mobile phone coverage by:
  - 1 company
  - 2 companies
  - 3 or more companies
The goal is to partner with organizations and use outreach programs to connect each satellite campus to one another, allowing each one to learn from one another. One potential partner organization, ‘Teach a Man To Fish’, collaborates with schools through the implementation of educational projects to encourage self-sufficiency. Basing the funding system on existing models, Dega Senior Secondary School will establish a platform for a self-sustaining campus and business through the implementation of small scale technology ventures. These ventures relate to the agricultural nature of the local community, inviting members of the village to take part in the ownership of the model. By including the community members as well as the students, and inviting the new workers of the technology hub, an array of occupational opportunities are created.

The inclusion of the community members into the campus provides local villagers with access to resources not previously available, such as the research library materials, lab equipment, and agricultural processing equipment for designing and creating new methods of food processing. It also provides the residents of New Longoro with a sense of ownership in the construction and operation of the campus facilities, which is necessary due to the fact that the village self-funded the construction of the existing building on site.
"As Africans, we are the ones who understand Africa the best. We see situations from the ground. We are involved with what's happening. So, when we are coming up with solutions, we come up with solutions for problems we know."

-Amos Gichamba, mobile app developer of dairy farming app in Kenya
Software development has been growing and evolving rapidly, expanding across many professions. With the recent interest in technology and software development across West Africa, international as well as locally-geared apps are gaining more recognition and popularity. Text message phone apps allow Africans to check market prices, transfer money, learn languages and connect with other farmers or professionals in different regions without ever stepping foot out of their villages.

“The work of these mobile developers is buoyed in part by the fact that while wired telephone lines and broadband Internet connections are very rare in Africa, cell phone use is exploding. Mobile phone subscriptions in Africa are growing at a rate of about 50 percent per year in recent years, faster than that of any other continent, according to the International Telecommunication Union. A 2009 ITU report found 28 percent of people in Africa have a mobile phone subscription. By contrast, only 5 percent of people there use the Internet, the ITU says.”


Series of agriculture and energy-related apps developed by and for Sub-Saharan African counties
Lack of development and resources in rural regions lead to scarce educational opportunities

The site is located in the central part of Ghana within the region of Brong-Ahafo, and shares characteristics with other northern regions of sparse development and rural settlements, leading to a scenario typical of northern Ghana where schools are few and far between. This leaves many rural villages without a school nearby, only worsening the problems associated with lack of available education: low literacy rates and southern migration.

The site of the thesis is located in the rural village of New Longoro, typical of other rural villages in the region, but fortunate to have the existence of Dega Senior Secondary School which was finished construction in March 2013. Due to the lack of other secondary schools in the region, Dega Senior Secondary School is host to 102 students coming from 39 different villages within the Brong-Ahafo region. With the lack of public transportation, often the only means for students to attend schools in rural regions is to move in with distant relatives that live in a village with a school, or to live in dormitories set up through the school and operated by a teacher-in-residence. The diagram below shows the various home villages that current students of Dega Senior Secondary School come from in order to live in New Longoro and further their education.
III: UNDER THE MANGO TREE

A place for innovative learning, technological collaboration, and cultural appreciation
This project started during January 2013 with a needs assessment for Dega Senior Secondary School in terms of construction, design, interior rooms, functionality, furniture, and school supplies. An assessment of these categories provided valuable insight for measuring the current state of the school, and making sure the facilities are working efficiently to serve the students and teachers. A series of methods were used as information-gathering tools, such as interviews with various teachers, students, and project collaborators in order to gain a better understanding of the existing conditions. With improvements in facilities and design, DESS will encourage maximum enrollment and improved grades for students.

Through an analysis of precedent schools designed in similar contexts, research on local and vernacular construction materials as well as contemporary building methods in Ghana and other West African countries, the goal is to design an improved and systemic set of buildings to accompany the classrooms currently in construction on the site.

**Project Goals:**


2) Design a funding strategy that creates a micro-economic school system with income-generating features that allows for affordable education.

3) Make a proposal to the Ghanaian government arguing for the financial support of DESS and reform of education in rural Ghanaian schools.

Dega Senior Secondary School (DESS), located in the Brong-Ahafo region in Ghana, West Africa, provides affordable secondary education for 150 students that come from 39 different villages surrounding the village of New Longoro where the school resides. The current students of DESS are displaced and share facilities with the Junior Senior Secondary school because they are awaiting funding to finish construction of their first campus building that contains three classrooms, a workroom, and a small storage closet. The private, community-owned school has plans to start design and construction on several other buildings for the high school campus, with programs including an innovation center, research library, computer lab, science lab, dorm facilities administration offices and additional classrooms.

The problem that arises from the project is the need for a project funding strategy and a more affordable construction process, systemic design of the entire site planning project, and the utilization of more local materials that allow for a sustainable and vernacular collection of buildings that are interconnected in terms of energy, resources, and programmatic functionality.
Research for the Dega Senior Secondary School site planning project began in January 2013 when I first visited Ghana with the MIT D-Labs team through a class I participated in the previous fall semester. I chose to continue the project for my thesis, allowing for a more holistic and detailed approach of the systemic design that the community of New Longoro was in need of.

Timeline of the project:
January 2013 - Traveled to Ghana with Amy Smith and a team D-Labs students. Work on site design included gathering soil samples, taking measurements, conducting interviews with several members of the community who include the school headmaster, the students, several teachers, and other prominent members of the New Longoro community.
February - May 2013: Thesis Prep Class. Developed thesis topic from the information gathered during the Ghana trip, and proceeded in research phase by collecting information to set up the thesis argument and act as the foundation for the design project.
September - November 2013: Maintained frequent contact with two members of the New Longoro community. Timothy, an influential member of the community and Nathaniel, the headmaster of Dega Senior Secondary School. Began design phase of actual school site plan, developed architectural language meeting the desires of the community, completed workshop of compressed earth block construction and conducted several tests on durability of earth bricks compared to concrete aggregate bricks.
December 2013: Finished the design and research proposal and presented the final thesis defense in the MIT Media Lab on December 19, 2013.
SITE ANALYSES

Rotate orientation of buildings to accommodate for the southwestern prevailing wind direction for maximum natural ventilation.

Take advantage of natural slope of the landscape for agricultural and athletic fields, and other landscaping programs.

Consider relation to exporting in southern regions and connecting to communities in northern regions.
Black Volta River / Water Access
Winch-Bole Road / Main Road
New Longoro Village
Existing DESS Classrooms (currently in Construction)
Existing Buildings on Site
DESS Property Site Boundaries
In the regional map of the site, located in Brong-Ahafo, Ghana, is the village of New Longoro. Like many traditional Ghanaian villages, there are informal market shacks that line the roadside, mud huts as the typical housing typology, and public spaces that mediate between the buildings and the roads. New Longoro is a unique village, however, due to its close proximity to one of the few rivers in Ghana, the Black Volta River, and its community members that strive to encourage education amongst the youth. New Longoro is also unique in its dedication to the progress of education in the region, and the community members of the village self-funded the construction of a high school that provides education for over 100 students at heavily subsidized costs (25% of what a typical high school costs in Ghana). Since the Ghanaian government does not support high school education, the enrollment rates are drastically high since tuition and fees are unaffordable to most families. Unlike American education system, private schools are often cheaper than ‘public’ government schools because the costs are usually burdened by donors.

Incorporation of design strategies such as utilizing natural energy resources such as solar or wind, rainwater harvesting, and cyclical sanitation systems is a way to approaching systemic and self-sustaining campus for the senior secondary school. Rainwater management is extremely important in the West African context, since students have to spend time each day walking to the nearest well and drawing water. Not only does this take away from their actual classroom time since it is done during school hours, but the water is unfiltered and is often contaminated leading to illnesses and absences in school.
DESS RE-IMAGINED

The collective campus not only creates a space where professionals, local community members and students interact around education, agricultural production, and an entrepreneurial system that support the local economy and education of the youth. This system of growing food more productively and creating an education built around it that fosters community participation within the school and introduces technologies that forward already existing local markets and systems. Not only does this generate a sense of community between the village, the school, and the tech hub workers but it also creates opportunities for the local farmers to be more connected and have access to the outside agricultural markets, and gain an understanding of how to farm more productively, both in testing new ways and crop cultivation and an improved method for marketing. Mobile applications allow farmers across regions to learn more productive farming methods, from the best time to harvest, to new cultivation techniques and how to access fluctuating market prices to sell their crops at the right time for the right price.

Introducing a series of agricultural and related cultivations, the crops themselves become both a testing bed for testing new software development as well as a cash crop production that the students and community members can take part in keeping as a means of generating income to support the school itself. Each of the proposed crops are catered to ones that already exist and thrive in the region, including the ‘superfood’ Moringa plant, mangoes, yam, cassava, tomatoes, and plantains, as well as introducing bamboo groves that once reaches maturity will act as a building material for the village that can also be exported to other villages close in the region. This serves as another means of income generation for the development of the self-sustaining school.
The design re-envisiones and redefines the perimeters of a campus for secondary school education architecturally, testing new programmatic relationships within an educational environment. This includes the combination of programs including a school, technology center, and agricultural production system, in order to create a self-sustaining, entrepreneurial education system and a technology-centered secondary school, which will act as advocate for reform of private sector school system to the Ghanaian government.

The goal is to design a self-sustaining collection of buildings for the school’s campus that facilitate and encourage learning in the West African school system, while also focusing on drastically minimizing student fees in order to increase enrollment and provide affordable education to Ghanaian youth. By designing a funding system as well as a school, the school administration will be able to support the influx of students, subsidize student fees by providing scholarships, support teachers wages, and purchase necessary school supplies such as furnishings and books. 

company post-graduation. In addition, the company would provide trainers for additional English and computer classes, to further build students’ professional skill set.
The community-technology spiral encircles a large mango tree which is the center of the campus design. It surrounds the excavated courtyard that acts as an open air auditorium for the students of DESS and the village meeting center for New Longoro. The main buildings are the existing building converted to an indoor market and agricultural processing center, the community innovation center, and the technology hub.

The tech-hub will act as a satellite to provide resources for the local rural populations by targeting Ghanaian tech-related companies in the Brong-Ahafo region with an interest in permaculture or app development that focuses on testing and improving agriculture cultivation or marketing. By creating adjacent programs of technology and innovation, and business and marketing, farmers, students, and tech-workers will interact and collaborate on projects. By incentivizing a local company, or host of companies, to invest in building the Innovation Center, a relationship between the school the community, and the company will develop with time.

The Innovation Center will act as liaison, linking the school to the company. The company will then send representatives from industry to train high school students through internships, and equip them with the technology and innovation/ business and marketing skills that they need to work in the company post-graduation. In addition, the company would provide trainers for additional English and computer classes, to further build students’ professional skill set.

This innovation center will provide a direct linkage between the school and the community itself, which now acts as two independent systems. The innovation center will also act as a satellite of the company investor, creating both a local and regional and global series of relationships that will each be tied to DESS.
i. What it is: A center for New Longoro students, visiting scholars and the local artisans in the community to use as a starting point for projects.

ii. What is included in it: Intended programs include a research library with textbooks available for student and community use, a meeting/conference room, a computer lab, a workshop for metal and woodworking with operable machinery, storage space for materials and supplies, and an adjacent gallery to be used for marketing, selling and displaying the constructed technologies.

iii. How it will be used: This center can work to promote the understanding of the importance of higher-level education among the students and local citizens by holding various classes, providing resources, and addressing locally-appropriate design issues within agriculture, business, and educational related industries.
Longitudinal section through the New Longoro Community Innovation Center and adjacent water storage tank that collects enough water to supply 50 students for one month during the dry seasons.
AGRICULTURAL TEST-BEDS

Classroom designs focus on cultivation and processing of small-scale, income-generating projects.

The main crops that the cultivation classrooms will focus on processing include the Moringa plant leaves, Moringa seeds, mushrooms, honey and beeswax as a byproduct. Each form of crop cultivation requires a specific type of space for processing:

a) Moringa leaves need linear beds spaced in 1’ rows and horizontal netted areas for drying
b) Moringa seeds need similar linear spaces for cultivation, as well as ground locations for pressing the seeds and extracting the oil
c) Mushroom cultivation require vertical spaces for storing the bags, as well as areas that can allow for easy watering
d) Honey and beeswax processing areas need both ground and shelf space for large pots for boiling and extraction
e) Agricultural processing equipment demands larger spaces for usage, as well as areas for plant storage
CLASSROOM 1
Moringa Plant Cultivation and Processing

CLASSROOM 2
Mushroom Cultivation and Soilbed Preparation

CLASSROOM 3
Honey Processing and Beeswax Extraction
Specific spatial development of agricultural processing informs the architecture of ‘tech-ed’

Each type of plant processing delivers a vast amount of products that allow for potential income generation to support both individual students and the school itself. With the connection of the telecommunications facilities at the technology hub, and the ability to test and develop agriculture and marketing apps, the school has the ability to sell its produce on the market for optimal prices. Apps not only provide invaluable insight to current market prices, but also offer the potential to compare with different regions, showing where the most profit is available in various cities for export.
Students working on their income-generating projects by harvesting Moringa plants, cultivating mushrooms in their dorms, and making beeswax candles.
D-LAB’s director, Amy Smith, and myself assisting the students with the beeswax candle-making process
A series of phasing diagrams showing the proposed evolution of the site development during the expected timeline of the construction to completion.

YEAR 1: Continue renovation and restoration of existing buildings on site. Begin management of business plan and development of agricultural plots.

YEAR 5: In construction phase of each spiral, including re-purposing the existing school, the technology hub, innovation center, one classroom and one dormitory.
YEAR 10: Beginning construction of second layer of each spiral, including second classroom and shared dining/study quarters for students.

YEAR 15: Beginning construction of tertiary layer of spirals, including third classroom and additional dormitory.
Located on West Africa’s Gulf of Guinea only a few degrees north of the Equator, Ghana maintains a steady temperature throughout the year. The image to the right shows the location of Ghana on the world map, including the density of global Internet connections overlaid with the annual climate data of rainfall, and high and low temperatures for Ghana. Ghana’s climate and geographical location makes it a prime candidate for rainwater harvesting. Due to irregular rainfall and the occurrence of wet and dry seasons, water scarcity is a large concern. “Irregular rainfall results in reduced production, wasted seed and inputs, and complicates the farmer’s planning process. Drought results in crop failure, livestock losses, malnutrition, and increased health risks.”

Wind rose for ventilation of the Brong-Ahafo region (left) and the sun path diagram for the DESS site in New Longoro (right)
Rainwater collection tests were calculated based on the digital model concluded that rainwater collected during the months of April through October could provide enough water during the dry months of November through March.
Incorporation of design strategies such as utilizing natural energy resources such as solar or wind, rainwater harvesting, and cyclical sanitation systems is a way to approaching systemic and self-sustaining campus for the senior secondary school. Rainwater management is extremely important in the West African context, since students have to spend time each day walking to the nearest well and drawing water. Not only does this take away from their actual classroom time since it is done during school hours, but the water is unfiltered and is often contaminated leading to illnesses and absences in school.

The graphs to the right represent the thermal production of the existing school and proposed new buildings to show the benefits of rammed earth walls and roofing insulation. The interior temperature comfort level is severely decreased by the addition of the rammed earth construction, due to their high thermal mass and ability to absorb and store heat. This allows the teaching environment to be more comfortable for teachers and students, encouraging a better learning environment for DESS.
THE THERMAL ENVIRONMENT

OUTSIDE UNDER A THICK SHADE

OUTSIDE IN THE SUN

INSIDE THE EXISTING BUILDING

INSIDE THE NEW BUILDINGS

THE THERMAL STRATEGIES OF THE NEW BUILDING

USING THE EXISTING BLDG CONSTRUCTION METHODS

WITH 2" THICK ROOF INSULATION

WITH SCREENS ON WINDOWS (BLOCKING 50% OF SUN)

WITH THERMAL MASSIVE WALLS (24" THICK)
An important part of working with a rural village in Ghana is communicating the design proposal and research to the community members of New Longoro. Since the village is mostly composed of farmers, as well as the teachers, parents and students of Dega Senior Secondary School, the audience is not one of architecture or construction professionals like the audience of the thesis defense jury. The students and the community members will be constructing the buildings themselves, therefore representations of the drawings are more easily communicated through a series of familiar drawings: a comic strip that includes pictures of the students and villagers themselves, with a step-by-step visual and written manual of how to construct the formwork, walls, and roofs.

By using images of the students and using terminology that is common to New Longoro, the process of construction and facilitation of design addresses familiarity with the locals. This allows local residents to easily communicate amongst themselves and take ownership of the proposed designs and usage of material suggestions. The relationship of the community and the campus will be strengthened, leading the locals to be more involved in the design and construction decision making processes.
First layer of formwork is started with assembling plywood sheets in excavated foundation.

Concrete base is made in excavated ground to provide support base and foundation for rammed earth walls.

Plywood sheets are constructed to make the form of the wall.
Second layer of formwork is started with assembling plywood sheets on top of existing formwork. Wooden ties reinforced with rebar are added to the formwork bracing. The first layer of formwork is filled with earth-cement mixture (see earth-mixture manual) and compressed with tamping method until formwork is completely filled to create the base of the rammed earth wall (see tamping construction manual). Secondary timber reinforcement is used as cross-bracing to support plywood sheets.
Complete formwork is filled with earth-cement mixture and compressed with tamping method until formwork is completely filled to create rammed earth wall.

Second layer of cross-bracing is built onto plywood sheets

Rebar is added spanning across and through the plywood sheets, tied back by the outer layer of bracing to keep the formwork in place when earth is compacted during tamping process.

Outer layer of bracing is added to support cross-bracing
Series of drawings to show the process of constructing the two different systems of structural support trusses for construction and assemblage of the roof.
Axonometric drawing of the technology hub and innovation center, highlighting the roof structural system that includes two types of sloping trusses, which allow the rammed earth walls to be load bearing and take the support of the roof system. The secondary trusses in between are used when the span between the butterfly trusses is too great.
The main factors of material selection in the construction of the buildings deal with cost versus longevity, as well as the distance the materials are located from the rural village of New Longoro. The focus was to create an architecture inspired by the local vernacular and material palate while also taking into consideration how the intersection of tech-hub, community center, and secondary school programs use materiality as an opportunity for a new relationship between the people of New Longoro and the buildings on the new collective campus.

Through analyzing existing techniques of alternative and non-conventional construction methods using local and readily-available materials (focusing both on traditional building materials and taking advantage of utilizing materials not typically used in construction), the project takes a holistic design process and provides a catalog and methodology for using easily attainable, low-cost materials as viable building solutions for a West African context. Use of traditional materials in modern day construction was generally implied that it represented the past, not present day construction techniques, and was avoided.¹ With a shift towards sustainable and local materials, especially in fields on development, traditional materials are being commonly used again.

The study and re-application of common material elements has the ability to alter the functionality of traditional construction methods, weaving together typically segregated systems in rural Ghana. Issues of sanitation, health, education, construction, and funding strategies are often viewed as separate entities where local community members attempt to design and construct each system independently. In places where infrastructural and structural systems are thought of as isolated systems, how can systemic design alter the relationship between buildings and their infrastructures? Between buildings and their inhabitants? Between education and both local and regional industries? Can innovative construction and material-use allow for infrastructure and construction to be more affordable in the rural, sub-Saharan context? By designing a systemic campus for the school that consists of sanitation, natural energy, resources and local materials, the cost of building decreases while creating connectivity between once segregated systems.

<table>
<thead>
<tr>
<th>Material</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete Mix</td>
<td>$9/bag</td>
</tr>
<tr>
<td>Gravel</td>
<td>$62/truckload</td>
</tr>
<tr>
<td>Quarry stones</td>
<td>$831/truckload</td>
</tr>
<tr>
<td>Sand</td>
<td>$62/truckload</td>
</tr>
<tr>
<td>Wood</td>
<td>$3-5/piece</td>
</tr>
<tr>
<td>Bamboo</td>
<td></td>
</tr>
<tr>
<td>Earth</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** The price for Sand is $62/truckload, not $62/bag as initially stated.
DESS students carrying the compressed earth bricks used in the construction of the existing school’s walls (left) and students digging the foundation.
Examples of the traditional vernacular that represents the majority of buildings in New Longoro
Final 1:50 scale model of the technology hub displaying the rammed earth walls (figure 5.1) and the walls with the structure of the roof system (figure 5.2).
Overhead view of the technology hub (figure 5.3), interior perspective (figure 5.4), and sectional perspective (figure 5.5) of the technology hub model without roof structure and perpendicular walls made of compressed earth blocks (CEB).
Figure 5.6: Final 1:200 scale site model of the proposed design for Dega Senior Secondary School (viewed looking northwest).
Figure 5.7: Overlooking the technology hub and community innovation center (viewed looking north).
Figure 5.8: Final 1:100 scale model of the technology hub and community innovation center surrounding the courtyard.
Figure 5.9: Final 1:100 scale model of the courtyard and ‘community-technology’ spiral creating a gathering space for the village (viewed looking south).
Figure 5.10 and 5.11: Process of making a 1:25 scale model of the formwork for the rammed earth wall, using a combination of cement mix, earth, sand, peat gravel, and water. The model was tamped into three separate layers, each using a slightly different ratio of ingredients in order to test consistency.
Figure 5.12: Evolution of the formwork model in process and the final 1:25 scale model as a physical demonstration to show the process of constructing a rammed earth formwork wall (Fig. 5.13 and 5.14).
Process of testing the soil and pouring earth, sand, and water mixture into molds for compressed earth bricks (CEB), a similar process used in the construction of the existing D.E.S.S. building. For this test, three CEBs were made from the following ratios: 10 parts sand, 4 parts clay, 1 part water, 3 parts gravel, and 3 parts earth. Note: Soil was collected from local source in Cambridge, Massachusetts and set to dry inside to avoid rain and cold temperatures.
Preparing the compressed bricks for demolition in order to test their endurance compared to bricks made of various ratios of cement, sand, and earth.
APPENDIX I.

Documentation from Dega Senior Secondary School and New Longoro, Ghana
Nathaniel, the headmaster (principle) of DESS, and the residents of New Longoro recently sent an update in November 2013 about a pressing challenge the students were facing. Several students were unable to afford registration fees in order to take the WASSCE. The WASSCE is the West African equivalent of the SAT, and is required in order to pursue any form of tertiary learning (trade or technical schools as well as universities). Since DESS is a private school funded by the village of New Longoro itself it does not receive aid from the government, and thus its 45 senior level students are responsible for paying the high registration fees for the exam (approximately $325 USD per student). With the majority of these students supporting themselves and their personal education endeavors in secondary school and tertiary school, these expenses were unaffordable and a large obstacle in the way of their pursuit for continuing their education.

Over the course of one week, a part of my thesis responsibilities revolved around marketing a campaign for these students in order to supply some of the costs needed for the students to take the exam. In less than one week $1,270 was raised through a YouCaring campaign, with an additional $2,600 raised by a fellow D-Labs team member through an MIT EASE grant. In total, eight of the 12 students were able to gather full funding for the exam due to the campaign and grant money raised.
November 25, 2013

Dear MIT,

This is to inform you that $6,300 dollars has been paid to the National Schools Service (NSS) to register the following students for their WASSCE exam:

James Bonahoe, Patrick Forger, Wimfreed Hawie, Grace Kala, Jonathan Kaemabong, Linda Limbodega, James Mentele, Helina Noah

These 8 students have worked exceptionally hard over the past 3 years but due to poverty, have been unable to pay for their WASSCE exam, the main determining factor in proceeding to higher levels of education. We are thankful to MIT Expanding Access to Standard Education (EASE) for coming to our aid and supporting these students and want to thank MIT in advance for reimbursing our financier Emmanuel Kitcher with EASE’s scholarship funds.

Sincerely,

Headmaster

MIT EASE grant letter and YouCaring campaign website showing the funds raised for the DESS students allowing them to register for the WASSCE exam.
Important contacts for New Longoro

Nathaniel, Headmaster of Dega Senior Secondary School
Nathaniel is the visionary behind making DESS the “new MIT of Ghana’s secondary schools.” He is both knowledgeable of the needs of the facilities, teachers, and students, and is able to provide invaluable information regarding the needs for the village of New Longoro. He has been very involved in the design and construction of existing school building, and is the main contact regarding the project.

Yaw Kuffour Sarbeng, recent graduate student with a Masters of Architecture from KNUST (Kwame Nkrumah University of Science and Technology)
Yaw has experience in both professional design and construction in Ghana, as well as familiarity with the West African climate and firsthand experience with the Ghanaian education system. He helped with the site and existing building analysis, as well as collecting soil samples from the site in order to test for durability in compressed earth brick making and rammed earth construction possibilities.

Kwami Williams, teaching assistant from MIT D-Labs course
Kwami is an important contact for the development of the project because of his ties to MIT, D-Labs, and Ghana. Throughout the last year Kwami has spent time traveling back and forth from Ghana to the US and has helped with gathering data in New Longoro and relaying information between the community of New Longoro and myself.
Letters from current Dega Senior Secondary School students

I am Magiwe Patrick, from Yaba under Kintampo

I was born on the 2nd of May, 1998. I am the only child of Mr. and Mrs. Aminu. My parents are still

Life at the Senior High School is indeed

I have a younger sister. She is in grade three

My name is Amofo Gabriel

I am a boy of 22 years old and I grew up in New

My name is Amofo Gabriel

I am a boy of 22 years old and I grew up in New

For this reason I have planned to help the future

Ofori Ama

Ofori Ama

For this reason I have planned to help the future

45

96
My name is Nsoh Hetema. I come from a family in the Brong Ahafo Region of Ghana. I have five children, and all of them are girls.

My parents are Mr. and Mrs. Kwegyir. My father is a farmer, and he also owns a small business. My mother is a housewife.

When I was young, I wanted to become a journalist. But due to financial constraints, I had to drop out of school at a young age. I had to work in the fields to support my family.

I decided to re-enroll in school and I enrolled in a local school. I had to work hard to complete my education.

I want to become a journalist. I want to write about the challenges we face as a family, especially the financial challenges.

I want to better my life. I want to educate my children. I want to make a difference in my community.

I want to establish a school and a hospital in my community. I want to help others.

I want to make a difference in my life. I want to make a difference in the lives of others.
Letters from current Dega Senior Secondary School students

My Name is Inuwa. I am a male. I am 19 years old. I was born in Kano in the Northern Region of Nigeria. My parents are Musulmic and our family members all live in the same house. I am currently studying at Dega Senior Secondary School. I have good grades in my education, and I am hoping to get into a good university in the future.

My Name is Hamza. I am a male. I am 19 years old. I was born in Kano in the Northern Region of Nigeria. My parents are Musulmic and our family members all live in the same house. I am currently studying at Dega Senior Secondary School. I have good grades in my education, and I am hoping to get into a good university in the future.

My Name is Muhammad. I am a male. I am 19 years old. I was born in Kano in the Northern Region of Nigeria. My parents are Musulmic and our family members all live in the same house. I am currently studying at Dega Senior Secondary School. I have good grades in my education, and I am hoping to get into a good university in the future.

My Name is Sani. I am a male. I am 19 years old. I was born in Kano in the Northern Region of Nigeria. My parents are Musulmic and our family members all live in the same house. I am currently studying at Dega Senior Secondary School. I have good grades in my education, and I am hoping to get into a good university in the future.
My name is Kudako且设备.且我是16. I am a female and was born in July in the Northern Region. I grew up in Jimmy and attended my primary school there. My parents are Mr. and Mrs. Kudako. They are all alive and are at home. As of now, I have two sisters and two brothers.

In my village, there is no formal high school. So when I completed my primary education, I had to further my education to the junior high, which was not far from home. The next year, I completed my junior high education and had to further my education to the senior high. My parents sent me to nearby villages called Nakadding to further my education.

My father is a peasant farmer and does not get enough tools to clear my entire land. In school, I encountered many challenges because education is the key to success. I also had to fight for a successful life in the future. I was pushed in my state to secure a better future. I want to become a journalist. The financial difficulties are resulting in becoming a journalist. I wish to deliver effective journalism on the media as a state to come so as to help people in similar situations in our country. And I can only accomplish this with adequate education.

I am writing this paper very hard for the WASSCE certificate. It will help me to have access to the tertiary institution.
“I had good grades in my basic education certificate education which meant that I must further my education. This, I must confess, became the most difficult task of my life.”
-Helina, Aspiring doctor from Charra, Ghana

“At school, on every weekend and every holiday, I work to cater for my daily feeding, buying of notebooks, clothes, soap, and also pay my school fees. I am indeed going through all these struggles because education is the key to success...(and) can lead me to a successful life in the future.”
-Jonathan, Aspiring journalist from Brong-Ahafo, Ghana

“I work from dawn 'til dusk on vacation to secure funds for my fees, books, and other materials. There are times I have to abandon school and go out to work to secure some income.”
-James, Aspiring health professional from Chibrinyoa, Ghana
My name is Anya Helina, I come from Charra in the Brong Ahafo Region of Ghana. I was born on the 6th of June, 1994.

The name of my parents are Mr. and Mrs. Obour Mensah. Their occupation is food crop farming and livestock. Four siblings—a boy and three girls. My mother took care of me up to Class Five at Charra. When I proceeded to Class Six, I was sent to a woman of Techiman to continue my education there. I had no bond relationship with the woman, but she showed me a dear motherly care and sponsored the rest of my basic level education. I finally graduated from the Junior High School.

My dad and mum had a divorce when I was only six months old. This actually made my mother a peasant farmer, struggling to make ends meet in education. My other three siblings and me. The most painful aspect of my life is that my dad is still alive but is only refusing to cater for us.

I did well in my Basic Education Certificate Examination, which meant that I must further my education. This, I must confess, became the most hecumen task of my life. The woman I went to stay with at Techiman was fed up. It thereby meant that I must struggle on my own to educate myself. To survive, I had to work very well to get money in order to enroll at Dego Senior High School. I work so hard during weekends and on vacations to sustain myself, in buying books, paying my fees, securing shelter and other petty things just to make life moderate for me.

I had an ambition of becoming a medical doctor in life, but the circumstances as of now does not permit my dear ambition becoming a reality. My mother pressed so well on me to study diligently. This is why I successfully passed my BECE exam (WASSCE) for my Senior High education. This has really been a burden to me and I write to solicit for a very dear help.

The help if provided, will enable me write a successful exam and proceed to the tertiary level. This will actually enable me to have the full benefits of my education. I have planned of establishing a hospital for the community should my dream be realized.
Use the following chart to record the school's production; make the changes you think necessary for it to be useful to you.

<table>
<thead>
<tr>
<th>Products</th>
<th>Production goal for</th>
<th>Production as of</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Production</td>
<td>Dollar</td>
<td>Production</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analyzing the market: Who are the possible clients who could be reached with the school's production?

What does developing a product entail?
Complete the following business plan chart and you will create an outline that will help you in creating a final business plan.

<table>
<thead>
<tr>
<th>SUMMARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product</td>
</tr>
<tr>
<td>Market</td>
</tr>
<tr>
<td>Competition</td>
</tr>
<tr>
<td>Competitive advantage</td>
</tr>
<tr>
<td>Marketing and distribution</td>
</tr>
<tr>
<td>Investment required</td>
</tr>
<tr>
<td>Staff</td>
</tr>
</tbody>
</table>
Recent Photos of Dega Senior High School

Photo Credit: Kwami Williams
Existing Dega Senior High School building in New Longoro, Ghana. Photo Credit: Kwami Williams
APPENDIX II.

Preliminary Concept Models and Sketches
Sketches of site planning development process with a focus on circulation and community gathering space
Sketches of site planning development process focusing on the relationship of school and technology programs
Sketch models of mushroom plant cultivation walls and initial as well as more developed site plan models.
Sketch models of regional site model (including Black Volta River and New Longoro) and sketch models of site planning and organization
APPENDIX III.

Initial proposal presentations and Final Thesis Defense
Presenting beeswax harvesting as income generation project to an audience of local villagers in a community meeting as a part of D-Labs class and a precursor to thesis development.
Presenting to an audience of academics and professionals in MIT’s Media Lab

Final Thesis Defense
Cambridge, Massachusetts
December 19, 2013
# MIT Architecture

## M.Arch

### THESIS REVIEWS

#### December 19, 2013

<table>
<thead>
<tr>
<th>TIME</th>
<th>STUDENT</th>
<th>THESIS TITLE</th>
<th>GUEST REVIEWERS</th>
<th>MIT REVIEWERS</th>
</tr>
</thead>
</table>
| 9:15 - 10:15  | Toshiro Ishii - A4 | Joel Lumet, Mark Jacobson  
Wataru Motoda, Fumio Futatsuki, Tsubasa Nagakura  
Yong-Ho Chung, Gardenia Wolanski, Frazier Schrader  
J. Molina de la Serna, Alejandro Armendariz, Yuki Obara | Linda Roy, Eli Mitchell, J. Behrens, Timothy Hyde  
Marc Szwajcer, Svetlana Fedorova, Mark Paskin, Bert Westerner  
Dennis Lipski, Ian Mclennan, Amanda Lawrence  
Merrill Hodgson, Sean Lilly, Stacey Mazzella |arrivé, Andrew Sills  
Linda M. Lewis, Jose Sardon,  
Mark Goldklang |
| 10:15 - 11:15 | U. Huang - A5 | Joel Lumet, Mark Jacobson  
Wataru Motoda, Fumio Futatsuki, Tsubasa Nagakura  
Yong-Ho Chung, Gardenia Wolanski, Frazier Schrader  
J. Molina de la Serna, Alejandro Armendariz, Yuki Obara | Amanda Lawrence, David Lewis, Keith Whitaker, Sean Lilly  
Gabriel Ford, Ed Mitchell, Marc Szwajcer  
Linda M. Lewis, Amanda Lawrence | arrivé, Andrew Sills  
Linda M. Lewis, Jose Sardon,  
Mark Goldklang |
| 11:15 - 12:00 | Daniel Cowles - A5 | Joel Lumet, Anna Aleksey, Tsubasa Nagakura  
Wataru Motoda, Fumio Futatsuki, Tsubasa Nagakura  
Yong-Ho Chung, Gardenia Wolanski, Frazier Schrader  
J. Molina de la Serna, Alejandro Armendariz, Yuki Obara | Linda Roy, Eli Mitchell, J. Behrens, Timothy Hyde  
Marc Szwajcer, Svetlana Fedorova, Mark Paskin  
Dennis Lipski, Ian Mclennan, Amanda Lawrence  
Merrill Hodgson, Sean Lilly, Stacey Mazzella |arrivé, Andrew Sills  
Linda M. Lewis, Jose Sardon,  
Mark Goldklang |
| 12:15 - 1:15  | Joshua Char - A4 | Joel Lumet, Anna Aleksey, Tsubasa Nagakura  
Wataru Motoda, Fumio Futatsuki, Tsubasa Nagakura  
Yong-Ho Chung, Gardenia Wolanski, Frazier Schrader  
J. Molina de la Serna, Alejandro Armendariz, Yuki Obara | Amanda Lawrence, David Lewis, Keith Whitaker, Sean Lilly  
Gabriel Ford, Ed Mitchell, Marc Szwajcer  
Linda M. Lewis, Amanda Lawrence | arrivé, Andrew Sills  
Linda M. Lewis, Jose Sardon,  
Mark Goldklang |
| 2:00 - 2:55   | Benjamin Hooper - A5 | Joel Lumet, Anna Aleksey, Tsubasa Nagakura  
Wataru Motoda, Fumio Futatsuki, Tsubasa Nagakura  
Yong-Ho Chung, Gardenia Wolanski, Frazier Schrader  
J. Molina de la Serna, Alejandro Armendariz, Yuki Obara | Amanda Lawrence, David Lewis, Keith Whitaker, Sean Lilly  
Gabriel Ford, Ed Mitchell, Marc Szwajcer  
Linda M. Lewis, Amanda Lawrence | arrivé, Andrew Sills  
Linda M. Lewis, Jose Sardon,  
Mark Goldklang |

**NOTES:**
- Reception immediately follows review in the Watertower Garden.
ENTREPRENEURIAL TECH-ED.
Fusing Technology and Education to Fuel Income Generation Education in Rural Ghana

EDUCATIONAL DELINQUENCY
relationship between high costs of education and low enrollment rates for students

UNDER THE MANGO TREE
a place for learning, innovative collaboration, and cultural appreciation

Final Thesis Defense: Presentation Boards 1-3
Final Thesis Defense: Presentation Boards 7-9
APPENDIX IV.

Precedent Studies and Reference Projects
Precedent analysis table showing the project, square footage, cost, and programmatic category
GANDO SCHOOL LIBRARY
Material as cultural "found object": water vases sliced to become apertures for light and ventilation
Mesh Network diagrams that influenced the design and layout of regional distribution of tech-schools for ease of communication and connectivity
Various site planning design schemes tested throughout the thesis proposal phase
RADIAL TYPOLOGY | EACH CLASSROOM IS ATTACHED TO SINGLE VOCATIONAL TECH HUB UNIT

TECH-CENTERED TYPOLOGY | TECH-HUB CENTERED COURTYARD SEPARATED FROM SPIRALING CLASSROOMS

SPIRALING TYPOLOGY | TECH-HUB, CLASSROOM, AND STUDENT LIVING QUARTER STRIPS SPiral FROM CENTRAL COURTYARD
Badanes, Steve. Building Consensus in Design-Build Studios: Expanding architecture, design as activism. (Metropolis Books, 2008), 258-263.


Gamez, Jose and Susan Rogers. An Architecture of Change. (New York: Metropolis Books), 14-41.


Oliver, Pul. *Built to meet needs: Cultural issues in vernacular architecture.* (Amsterdam: Architectural, 2006).


Keleti, Peter. Learning and teaching the craft of architecture. (1981), 1-10.


