When the Goals Change, the Process Must Too

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Abstract

WPI's Ghana Project Center is developing smart villages that prioritize community needs through generative justice, empowerment, and self-sufficiency. The objective of this project was to create a formal design process for project teams using co-design principles, and to apply a continuous improvement approach to evaluate the process with respect to generative justice goals. Using process and workflow analysis tools, the smart village design process used by two project teams was analyzed to define an improved co-design process.

Acknowledgements

This project could not have been completed without the support and guidance I received from my advisors, Professor Sharon Johnson and Professor Robert Krueger. I would like to thank the WPI project teams for allowing me to observe and evaluate their work for data collection. I would also like to thank our partners in Ghana, including Julian Bennett, village chiefs, e-waste workers, and the students from Academic City University College (ACUC) who all worked hand in hand with the WPI teams.

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Chapter 1: Introduction

The global north has been using neo-liberal development as a tool to continue the legacy of colonization. Smart development has been identified as using information technology to empower cities and communities to provide better quality of life. Smart-development benefits and consequences are disproportionately distributed within these hierarchies of power (Escobar, 2014)**.** WPI's Ghana Project Center has been working to address this issue by unlearning and relearning ways of thinking and is seeking to move beyond these traditional ideologies. Therefore a new set of goals have been redefined around the generative justice principles of prioritizing community needs and supporting the people, culture, and resources that already exist in the villages. As part of the Ghana Project Center for 2022, teams of WPI students worked alongside their local partners to push development design beyond its current framework. Projects encompass smart development, but also other technologies. These teams used non-western design ideas including co-design and generative justice to reframe their work. However a formal step by step process to guide this design had not yet been defined.

The goal of this project is to map out an equitable and improved co-design process for the Ghana Project Center that puts generative justice in its forefront. The motivation for this project is to ensure that the new process does not uphold the systems the project center has been working on moving away from. The results of this project provide a framework for recommended process and work system components that will support future project teams in achieving generative justice goals.

To achieve this goal, I applied a continuous improvement approach by delving deep into previous smart village design processes to understand what works and what needs to be changed. First, I utilized SIPOC (Suppliers, Inputs, Process, Outputs, Customers) and swimlane diagrams to map out a traditional design process. Second, through co-design and generative justice intensive research and utilizing the SEIPS (Systems Engineering Initiative for Patient Safety) methodology and depth and breadth levers, I mapped out an initial new process. Third, exploring and analyzing the work of two 2022 Ghana Project Center teams through meetings with partners and students and using tools such as, PETT (People, Environments, Tools, Tasks) scans, people maps, and outcomes matrices, the new process was improved and updated until finalized.

The project report is organized as follows. Chapter 2 provides the background and literature review needed to understand the concepts and tools utilized in this project. A brief summary of smart villages, the traditional design process, WPI Ghana Project Center, generative justice, co-design, and the industrial engineering process improvement tools are described. The methodology is presented in Chapter 3, including the specific steps used to improve the traditional design process into the new process that promotes generative justice. The results of my work are presented in Chapter 4, including analysis of data from two project teams used as

case studies. Chapter 4 also presents the new improved co-design process. Lastly, Chapter 5 is a summary of the work done in this project and recommendations for future work.

Chapter 2: Background/Literature Review

2.1: The Smart Village

There have been many definitions for ‘smart’ when it comes to villages. A smart village is defined as a “community empowered by digital technology and open innovation platforms to access global markets” (Darwin et al., 2020). With around 3.4 billion people living in villages, the smart village has become one of the greatest opportunities to expand into the emerging market of villages around the world (Darwin, 2018). Global corporations and brands see these communities as an enormous, untapped source of potential for economic growth. In order for these companies and industry partners to expand their markets and offer the right products and services to the villagers, they need to understand what villagers want. This ultimately allows corporations to reveal what villagers are willing to pay for.

Therefore, smart village organizations are able to sell themselves as initiatives put in place to solve prevalent pain points by providing technologies along with innovative business models. Ideally, smart villages are intended to eradicate poverty, enhance the happiness index of rural populations, and achieve development by empowering people for economic growth through digital technologies. The text states that if making life better for the people living in rural villages and raising their happiness index was the only reason for smart villages, they would not succeed (Darwin, 2018).

2.2: The Traditional Design Process

Open innovation and pivoting methods are the two main processes used when developing technologies and business models for rural markets through shared value. Shared value is an approach to innovation in which companies look for ways to grow and sustain their own businesses and create societal value by addressing society’s needs and challenges. Open innovation is based around the free flow of knowledge where both the giver and receiver have value to exchange (Darwin et al., 2020). Figure 1 provides an overview of the process.

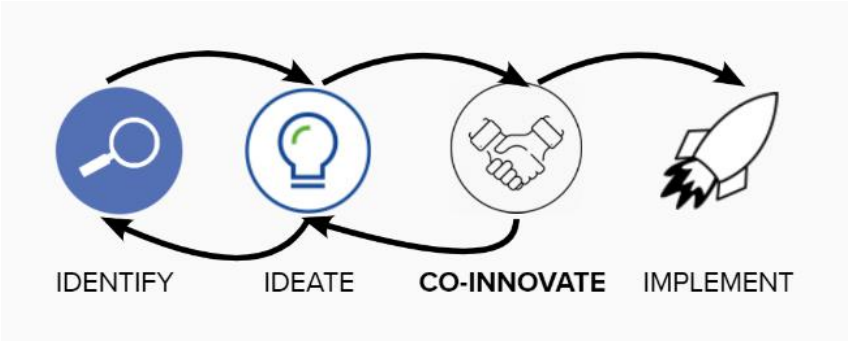

Figure 1: The typical/previous smart village design process

The process begins with examining the villagers' pain points and connecting them with the right pain-relieving agents (industry partners); this step is called identify. This step is crucial in order to achieve the goal of making life better for the people living in rural communities. However, these pain points must relate to a valid business opportunity to the providers such as startups and corporations. The second step in the process is to ideate, which is to help develop business models that optimize resource distribution and meet corporate objectives. The third step is to co-innovate, which includes business enterprises developing and delivering affordable technologies that rural villagers are willing to pay for. The iterative process is embedded in the co-innovate step. The iterative process uses training and awareness starting from the corporations, who then educate their fellows, fellows then train the smart village directors, directors help their interns who then educate the villagers and collect data and feedback, which goes back to the refine; technology offered by the industry partners. After identify, ideate, and co-innovate, innovations go through "proof of concept" which involves evaluating the sufficiency of the results in order to reiterate if needed; evaluation focuses on corporations' business needs. Lastly, these ideas are implemented and scaled.

2.3: WPI Ghana Project Center

WPI's Ghana Project Center alongside their local partners aim to push development design beyond its current framing by drawing on new design thinking, cross-cultural co-creation, and project-based learning, in ways that will re-conceptualize the relationship between so-called "western" experts and the communities they hope to serve. In 2022, there are a total of seven IQP and MQP teams working on co-designing smart villages in Ghana upholding the project center's vision. The student teams are working with a variety of local partners varying from village chiefs, Academic City University College (ACUC) students, local professors, local business entrepreneurs and more. In order to achieve this, a new set of goals have been redefined to prioritize community needs and to support what already exists in the villages. For these projects to truly benefit the community, it is necessary to disregard Western ideas of development and the typical process of creating smart villages and create a new process that upholds these reframed goals. Therefore, a co-design process was identified as a new methodology for creating an equitable new development process that puts generative justice at its forefront.

2.4: Generative Justice

Generative justice is defined as the universal right to generate unalienated value and directly participate in its benefits which achieves a fair and sustainable exchange of value (Eglash, 2016). This ensures communities of value generators have a self-sustaining path of circulation where value is not extracted and stays within the community. This concept allows equal benefits to everyone rather than one party having a status of more value for having more wealth. To break the pattern of alienated value an environment needs to be designed where value is circulated by the community. This ensures that value generators exchange value between peers

instead of hierarchical structures. These goals can be accomplished by working hand-in-hand with the local community; this is called co-design.

2.5: A Co-Design Process

Co-design aims to build on the idea of peer-to-peer generation by ensuring that the design process functions as a free exchange of ideas. A detailed co-design map developed by WPI Professor Elizabeth Long Lingo was used as the inspiration for creating a new design process that upholds generative justice goals. The map is shown in Figure 2.

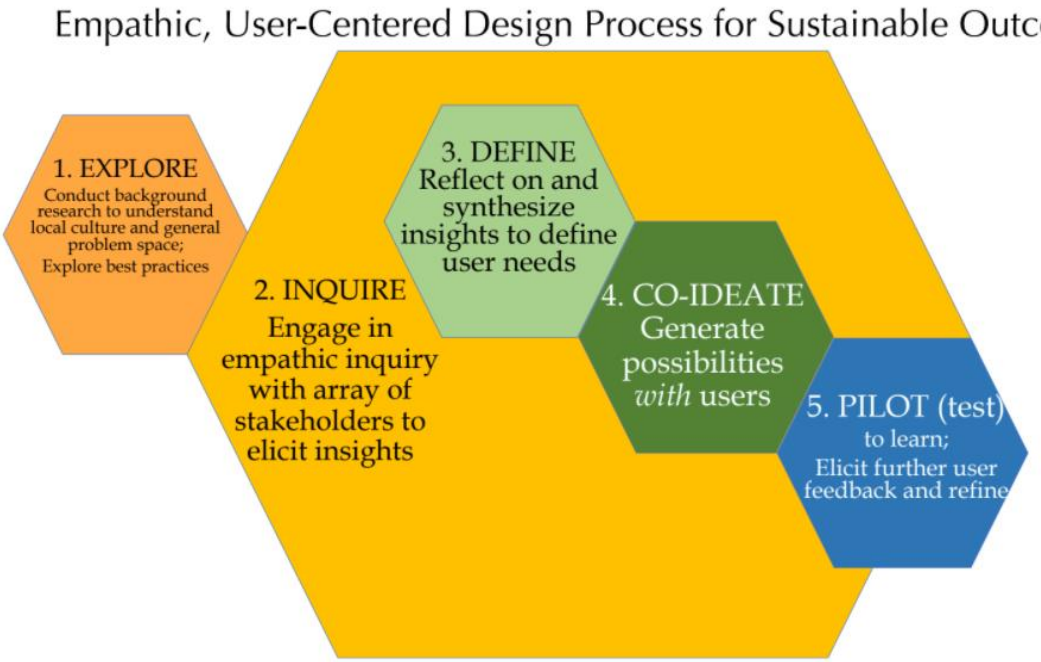

Figure 2: Steps of the co-design process

As shown in Figure 2, the only part of the process that is outside the realm of the stakeholders - in our case the villagers - is the exploration step. This first step in the co-design process includes conducting background research in order to understand local culture and the general to explore best practices. This step is crucial in order to gain the right amount of knowledge about the area before speaking with its people. Inquire is the second step, which is much more immersed with the stakeholders. Inquiry is done by engaging with stakeholders to elicit insights, which ensures that the user needs to be established in the next step are accurate and defined by the community themselves. The third step is to define the community needs, which is done through reflecting on and synthesizing the insights from the stakeholders. This definition step is still taking place within the realm of the community at stake, meaning consistent feedback and insights are being shared with the design team and the community members/stakeholders. The fourth step in the process is to co-ideate, which means generating possible solutions to problems with the users. This step helps both parties take advantage of the

strengths of each other and help one another think outside the box to come up with the most helpful solutions. Lastly, in order to maintain solutions, it is important to pilot and test out designs to elicit further user feedback and refine what is needed.

2.6: Process Improvement Tools

In order to ensure the design process used in the Ghana Project Center upholds the goals of generative justice, a set of six sigma and SEIPS process improvement tools were utilized in this project. A process improvement schematic was the main tool used to create a new process, as described in Chapter 3.

2.6.1: Six Sigma

Six sigma is a set of process improvement techniques that have been used in over 25% of Fortune 200 companies (Jones et al., 2010). The Six Sigma methodology includes many process improvement tools utilized in this project, such as SIPOC diagrams, process maps, and flow diagrams and swimlane diagrams.

SIPOC diagrams help define processes from start to finish and ensure the understanding of existing processes. SIPOC stands for Suppliers, Inputs, Process, Outputs, and Customers. The diagram is used to gather information regarding the existing process conditions in order to assess and narrow the scope of the most important problems. In this project, SIPOC diagrams were used to understand the typical smart village design process in order to identify gaps and limitations. The tool is also utilized in the project team case studies to support future recommendations.

Flow diagrams represent a flow or set of dynamic relationships in a system. A commonly used flow diagram utilized in this project is swimlane diagram. This type of diagram develops understanding of who is involved in what part of the process. Swimlane diagrams make it clear to their users what approach is being used in the process; top-down vs bottom-up approaches become more clear through these diagrams. They also show the types of interactions going on between the different stakeholders within a process.

2.6.2: SEIPS Model

In order to understand the context that occurs around the design process, a set of SEIPS tools were needed to consider the system as a whole. The SEIPS model is rooted in human-centered systems such as the creation of smart villages. It takes into account three major components of any system, the work system, processes, and outcomes as shown in Figure 3. This model dives into the major characteristics of each component and how the components affect and interact with one another. Within every work system, SEIPS takes into account how the people involved interact with the tools needed, tasks assigned, and environments (Holden, 2021). These

components will then interact with the work process and finally these result in the work outcomes.

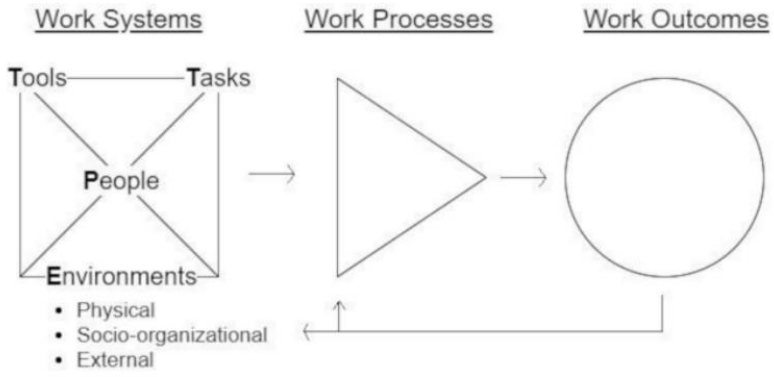

Figure 3: SEIPS model components and their interactions (Holden, 2021)

There are a number of SEIPS tools utilized in this paper in order to evaluate the case studies such as PETT scans, people maps, and outcomes matrices. A PETT scan summarizes the different components within a work system which include the people, environments, tools, and tasks and their interactions with one another. The PETT scan includes the barriers and facilitators of each of these components and their interactions. PETT scan is a flexible tool that can be used for intervention design in order to know which factors to address when creating new designs and data collection and analysis. Lastly PETT scans are great tools for understanding the priorities of the components within the work system against various factors. The second SEIPS model utilized was the people map which represents the various people involved in a work system and how they interact and relate with one another. The last SEIPs model used was the outcomes matrix which identifies the various desired outcomes and whether they represent the project outcomes and goals. In light of co-design and generative justice it is important to consider outcomes for various stakeholders and the outcomes matrix is a great tool to document that.

Another important concept utilized in this project is the concept of depth and breadth levers which are critical in transforming short term narrow-focus process improvements into long term solutions (Hall et al., 1994). The breath and depth levers go hand in hand with the SEIPS models in which both methodologies state that the outcomes of a process does not solely depend on the process itself. These depth levers include “roles and responsibilities; measurements and incentives; organizational structure; information and technology; shared values and skills.” All of these aspects of a work system are crucial to take into consideration when reframing smart villages to fit our new set of generative justice goals.

Chapter 3: Methodology

In order to achieve the project objective to design an improved development process addressing co-design and generative justice principles, I followed the continuous improvement approach outlined in Figure 4, which is an ongoing effort to improve processes through incremental improvements within an existing process (Soković et al., 2009). This schematic was chosen due to its ability to be used in a variety of projects. The process includes enough detail to follow but it is flexible enough to be altered based on the needs of each individual problem.

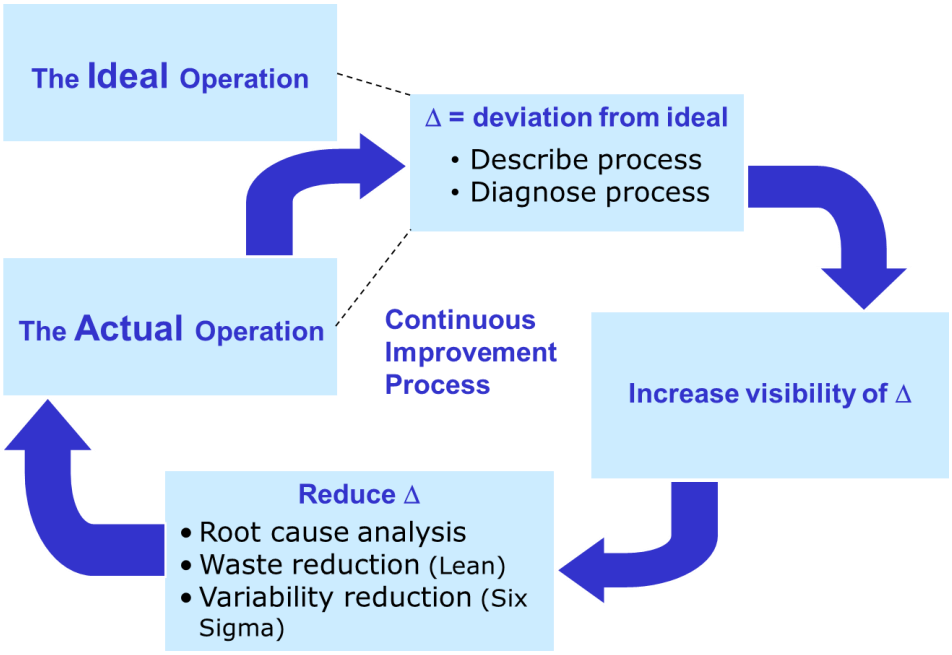

Figure 4: Process improvement schematic

3.2: The Traditional Design Process

The first step in my work was to explore the traditional design process, which in Figure 4 corresponds to "the Actual Operation". This step was accomplished by conducting background research and mainly exploring contents discussed in "How to Create Smart Villages (Darwin et al., 2020) which laid out the current steps of designing smart villages. This helped me to develop a better understanding of the goals and motives behind creating smart villages and allowed me to pinpoint the differences between those goals and the reframed goals identified for the Ghana Project Center. I then utilized a SIPOC diagram and swimlane diagram to summarize the information gathered and pinpoint the exact places that need improvement and those that do not.

3.3: Initial Co-Design Process

Given that project teams were only familiar with co-design principles and were not introduced to a formal step by step design process, my goal was to create a formal ideal process that could guide project center teams in their work. This initial framing of the process incorporated co-design principles, representing the ideal process in Figure 4. I did this by thoroughly understanding Figure 2, which is the co-design process mapped out by WPI Professor Elizabeth Long Lingo, in order to come up with an initial ideal design process based on generative justice goals. I also communicated with the Director of the Ghana Project Center, Professor Robert Kreuger, who provided helpful co-design and generative justice resources. Laying out the initial design process was crucial in order to then gain feedback and insight from the project teams and further understand the needed changes. This initial co-design process helped me understand the major differences between the traditional and co-design ideas.

3.4: Case Study Data Collection and Analysis

Two case studies were chosen from the current projects being completed in the Ghana Project Center to support the work of this project an MQP and an IQP team were chosen The MQP team was working on designing a Stirling engine that uses local e-waste materials and the IQP team was designing a business model to create value for the community using available plastic waste. These two teams were chosen based on the availability of their members and the variability in their projects.

3.4.1: Data Collection

Data was collected from these two case studies through interviews, observations, and informal group conversations. The initial meetings with the teams were held to understand their ways of going about their projects and how they were incorporating generative justice through their work. These meetings were essential for me to understand their goals, how they planned to achieve these goals, what generative justice looks like for each project, and where generative justice is lacking. By gathering this information, the goal was to compare with the initial ideal process to understand how to better fit and accommodate the needs of the different teams to accomplish generative justice goals.

Another source of data was observing team meetings with stakeholders and Ghanian partners. This helped me understand the types of interactions happening between all the different parties involved. In these observations, I sought to answer the following questions: how often were teams meeting with stakeholders? Who exactly did they meet with? The goals behind these meetings? Who initiated the ideas? And what are the limitations of these interactions? Lastly, I met with individual team members to gather feedback on the suggested new process. These discussions were helpful in making changes and revising the initial new process.

3.4.2: Data Analysis

SIPOC diagrams, swimlane diagrams, and SEIPS models were used to analyze the data collected for each team. SIPOC diagrams helped me better understand each of the teams' processes and compare their work with the typical process. I then used all the data collected from the teams and created swimlane diagrams that helped me better understand who did what in their processes and the sequence of the steps taken. I then used SEIPS models such as PETT scans, outcomes matrices, and people maps to explore breadth and depth levers of the system as a whole and what might be needed to change the outcomes of the process. The PETT - People, Environments, Tools, Tasks - scan considers the full breadth of the work system (Holden, 2021). Using this SEIP tool helped understand facilitators for the PETT scans components and their interactions with one another. People maps were used as an addition to represent the people involved in the system and how they interact with one another. The last SEIPS tool utilized was the outcomes matrix; this was one of the more important tools for data analysis. An outcomes matrix identifies the outcomes of interest and whether they match the project's goals, or in our case the generative justice goals. These tools were all crucial to understanding and are important to think about when making changes to the initial process in order to achieve reframed goals.

3.5: Revised Co-Design Process

Referencing the process improvement schematic in Figure 4, the data collection and analysis of the project teams were the main sources used to identify gaps, increasing the visibility between what the process is and how it should be. The final step was to try to reduce these gaps. After analyzing the data, I modified the initial process and mapped out a revised process. Changes were made along the way, then data was collected and analyzed until the “actual operation” deviated less from the “Idea operation” according to the process improvement schematic.

Chapter 4: Results/Discussion

In this chapter, the results of the entirety of the project are presented. The chapter begins with an analysis of the traditional process, which highlights the key deficiencies in the traditional process from a generative justice perspective. Section 4.2 presents the results of the two student project case studies and the key observations from their analysis. Lastly, section 4.3 presents the revised co-design process and the different components consisting of the work system, the process, and the outcomes that prioritize the goals of generative justice.

4.1: Analysis of Traditional Process and Initial Co-Design Process

The traditional design process discussed in Chapter 2 is described as the process of identifying the pain points of the villagers and the pain point relievers, ideating the possible business solutions, co-innovating with the different stakeholders and collecting feedback from the villagers, testing proof of concept solutions, and finally, implementation. Figure 5 showing the SIPOC diagram for the traditional process highlights some of the key elements such as who is involved and some of the major outcomes from such a process. Industry partners, corporations, smart villages organizations are some of the major beneficiaries of this process. These disproportionate benefits are shown in the outputs column; generating profit for industry partners by creating business opportunities, expanding markets and sales for global corporations, and lastly it is claimed that these smart villages will help villagers.

When used for designing the majority of current systems, this process often removes value from a community by making them consumers rather than collaborators. The entities that do generate value – in many cases the business corporations working on these solutions - often create a system of injustice which is observed in Figure 5. Although, at the first glance the traditional design process seems like an effective process for creating a smart village, in reality this process puts villagers' needs last and goes through many major steps without including those who are most impacted by this work. The feedback collected from the villages is to help corporations understand what pain points will generate the most profit for these corporations (Darwin et al., 2020). The organizations taking part in the smart village initiative will only target problems that provide profitable outcomes.

A good example of this would in responses to the opportunity to help millet farmers in India who were exploited by middlemen and did not have the option to add value to their raw materials. Nestle came to the rescue only after they confirmed that these challenges translated to a huge business opportunity (Darwin et al., 2020). The corporation stated that healthy nutrition is a core business to them and that organic, healthy millet bars would be a huge market within their scope.

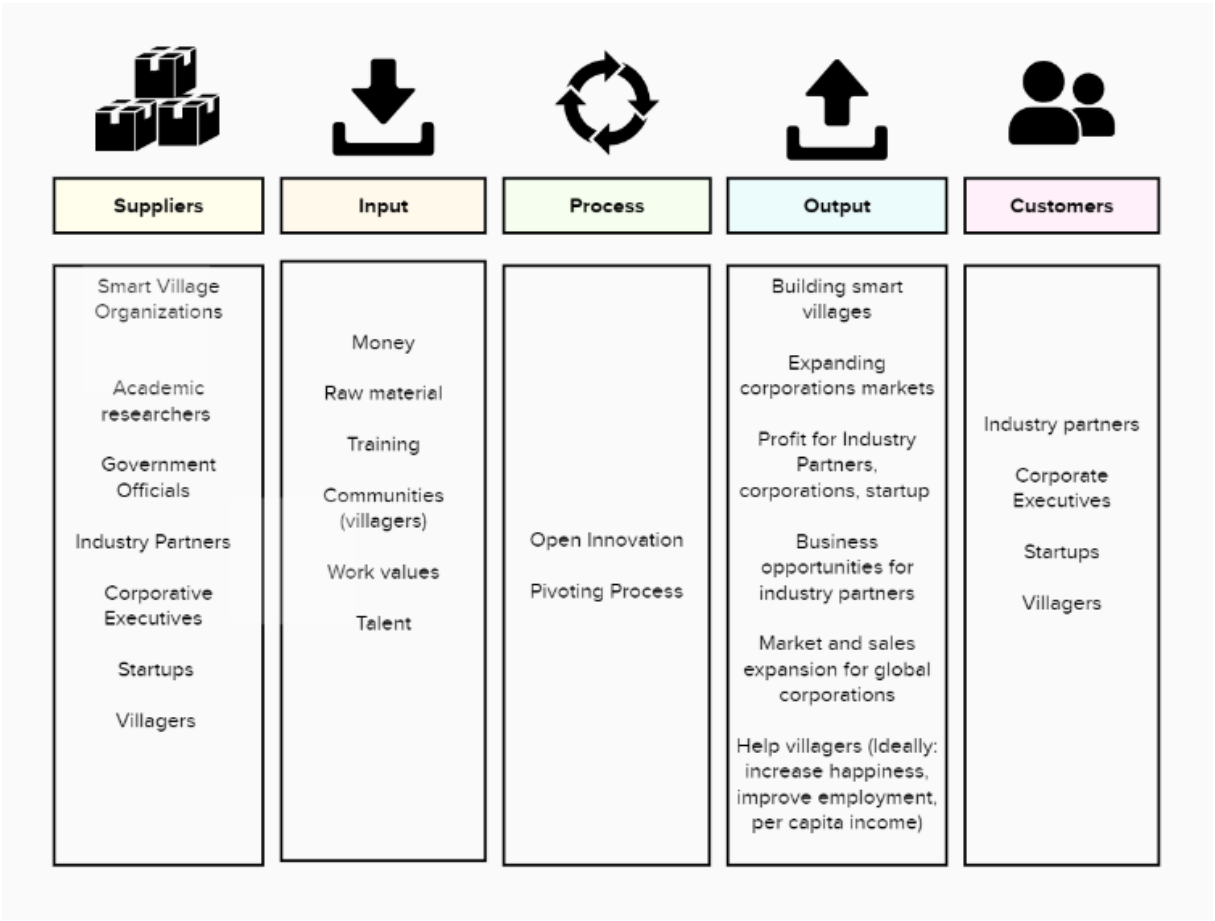

Figure 5: SIPOC diagram for traditional process

Traditionally, smart village projects only address community needs that will benefit these big corporations' goals. Western nations and companies generally act in their best interests without adapting to different cultures and customs. This reinforces the colonial aspect of any project in which developed nations pursue the goal to “help” a developing nation. In many cases, instead of serving marginalized people, Western researchers and academics make their own assumptions about these communities based on a few - if any - encounters with them (Smith, 2013). Development has come a long way, but without reallocating power back to countries healing from the impacts of colonization and allowing the most marginalized to make their own decisions, positive change will not happen.

The main issues with the traditional design process are not the specified process steps but rather the motivation behind them and the system in which the process takes place. Therefore, changing the goals behind the smart village development process is a first step to changing the results themselves. With the new goals of generative justice comes a new process, a process that puts the villagers first and works hand in hand with partners on the ground to co-design

innovative solutions to issues identified by the people. Generative justice ensures that value is generated within the community and is sustained through community members. The co-design process mentioned in Chapter 2 aligns with the ultimate goal of promoting generative justice through the work of the Ghana Project Center. Including the community in the majority of the design process ensures the solutions being implemented are from and for the people themselves. It secures sustainable implementation and promotes self-sufficiency because the villagers are aware of the resources available in the community and are experts in the design process of maintaining these solutions in the long run.

In light of the co-design process map and generative justice definition and goals, an initial co-design process was developed for designing smart villages in Ghana and is shown in Figure 6. The smart village design team - which includes the WPI Ghana Project Center and students - should first talk to their Ghanaian partners. Communicating with the partners upfront is in place to discuss pain points, challenges, problems, community needs, and the resources available in order to outline what support is needed from the smart village design team. The next step would be to conduct background research in such areas, which includes understanding local culture, and exploring best practices. This step is equivalent to the explore step in the co-design process described in Chapter 2. Based on the empirical findings the design team can brainstorm ideas to share with their stakeholders. These ideas will be discussed with the community leaders/stakeholders/partners in order for the people on the ground to understand the current ideas and provide sufficient input and feedback. After addressing the feedback, the team can work on designing solutions. Furthermore, in order to acquire funding for these projects, the design team will then pitch these ideas to grassroot organizations, NGO's, corporations, and the local government. After funding is settled, both the design team and partners will work together on creating solutions. This helps the community partners make sure that solutions are feasible on the ground and become experts on the design themselves. After designs are built, they are ready to be piloted and tested. If this step is not successful in the eyes of the community, there is a need to reiterate and go back to brainstorming different solutions, this is called proof of concept. Designs are then implemented and sustained through community contribution to continue the work.

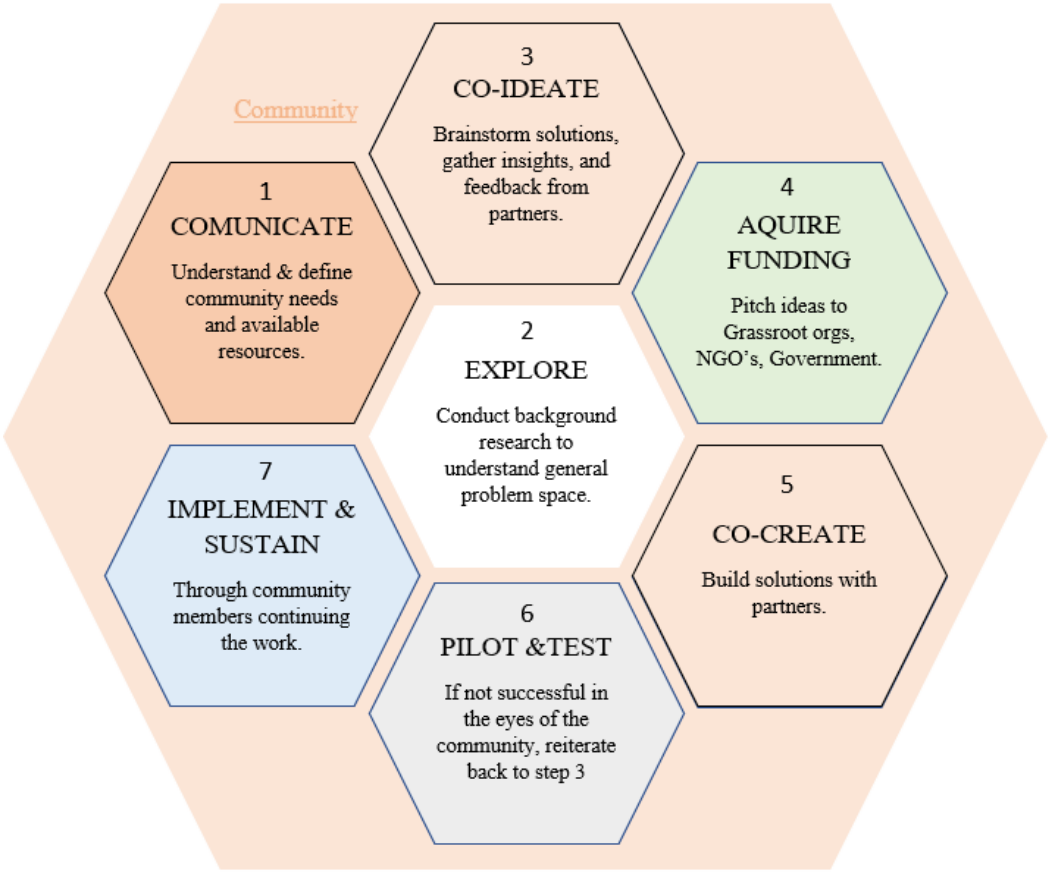

Figure 6: Initial new design process map

Although the goal of this new process is to move away from the old process in terms of its final goals, we find that some of the steps used in this updated process are very similar to the traditional one. This takes us back to the depth and breadth levers explained in Chapter 2. The depth levers include roles and responsibilities; measurements and incentives; organizational structure; information technology; shared values; and skills. This means that the steps in the process aren't the only factors in a system that affect the outcomes of a process, it is the system as a whole.

4.2: Case Studies and Analysis

In the following section, I explore the two case studies chosen to be observed in this project. These case studies helped me determine how the actual process was working and in describing and evaluating the two project teams, I was able to identify the gaps needed to be reduced which led to the improved co-design process. I utilized the SEIPS framework, and focused on the two teams work system, their design process, and outcomes. I met with the teams multiple times throughout the term to understand their work process and goals with respect to generative justice principals. Through meetings and observing the teams' interactions with local partners, I created swimlane diagrams and utilized SEIPS tools such as PETT scans, people maps, and outcomes matrix to further evaluate their work in terms of the reframed goals.

4.2.1: Case 1: Stirling Engine Project Team

The major goal of this project was to design a Stirling engine for manufacture using locally available parts in Ghana that can charge a cellphone. This team consisted of four WPI students who worked alongside ACUC students in Ghana and their professor. To ensure an effective solution, this team followed the following generative justice criteria: Involving the community users of the product in the design process, ensuring the design suits the needs of the community at time of completion and in the long term, and lastly creating a product that can be used safely by any individual in the community.

The first step in understanding this team's design process was to create a swimlane diagram of their work shown in Figure 7. This diagram shows the main three stakeholders involved in the process and the roles each played during the process. The Ghanaian partners are very involved in this process and the majority of the steps are the WPI students collaborating with the ACUC students. As seen in the figure, the local partners were the first to initiate project idea and were involved in co-ideating solutions with the WPI students and co-creating these solutions simultaneously.

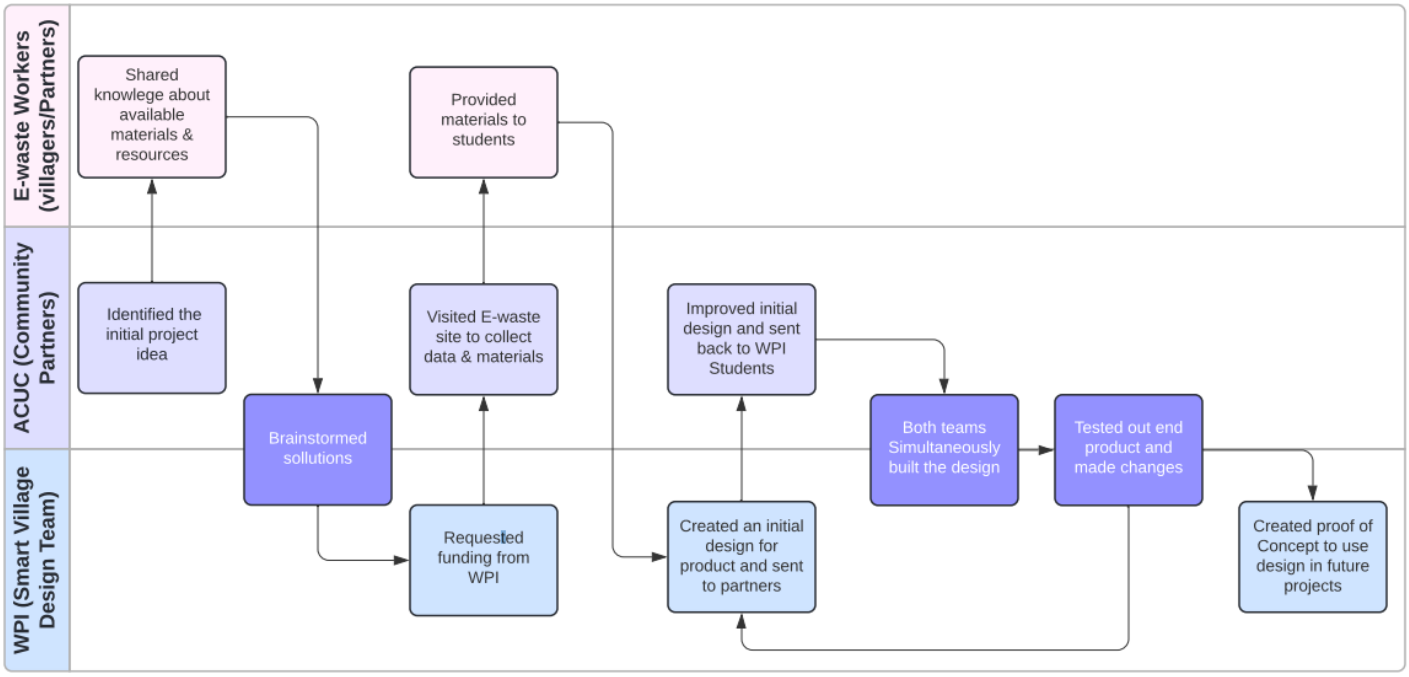

Figure 7: Swimlane diagram for the Stirling engine project

The second step was utilizing the PETT scan and the people map from the SEIPS models which provide an overview of the work system. The PETT scan includes the components of the work system that affect the end result. Figure 8 includes the people, environments, tools, tasks, and their interactions. Creating the PETT scan helped inform me about the barriers and facilitators for each factor that can affect the end result of the project. I identified these barriers

Factor	Barriers	Facilitators
People - Students (ACUC & WPI) - Professors (ACUC & WPI) - E-waste workers (Ghana & Worcester) - Ghanaian community	- Lack of time commitment from ACUC students due to different expectations	- Meetings with partners are productive - Positive teamwork between WPI students & ACUC students
Environments - Physical (Lab spaces in both WPI & ACUC) - Socio-organizational (WPI Project Center) - External (E-waste sites)	- Different time zone - Not being on the ground (distance)	- E-waste sites (Ghana & Worcester) have been a big provider of materials - Background support provided from the Ghana Project Center
Tools - Knowledge - Communication platforms - E-waste materials - Ideal Stirling engine	- Limited methods for contact - The ideal Stirling engine was difficult to get a hold of	- Access to an ideal Stirling engine gave a head start to the work
Tasks - Conduct research - Brainstorm ideas - Data collection - Design solutions - Test design - Implement solutions	- Limited data collection resources - Short time frame	- Brainstorming solutions with partners played a huge role in the success of the project - After testing, feedback given by local partners helped reshape solutions and made more impactful
Interactions (between People, Environments, Tools, & Tasks) - ACUC Professor provided the initial project idea - ACUC & WPI Students visited E-waste site - ACUC Professor and WPI Students met e-waste workers - ACUC students and WPI students met and shared ideas - ACUC students collected data and shared with WPI students - E-waste sites provided materials for project	- Miscommunication between WPI and ACUC students (people) due to limited ways of contact (tools) - Scheduling meetings (tasks) with different parties (people) is difficult - WPI students (people) do not have access to e-waste materials (tools) from the actual e-waste site (environment)	- Knowledge, information, and ideas (tools) are being shared between different parties (people) - Combined meetings with students, e-waste workers, professors (people) are helpful and make sure everyone understands where the project is going (tasks)

Figure 8: Stirling engine project PETT scan

and facilitators by observing team meetings and discussions with team members as well as the Director of the Ghana Project Center. As seen in Figure 8 most of the barriers are due to the project teams not being on the ground in Ghana because of the COVID-19 pandemic. Not being on the ground caused communication difficulties due to time zones, limited methods of contact, data collection shortages, inability to test local materials for designs and more. As for the facilitators for the Stirling engine team, they found interactions with local partners crucial to the success of their work, meetings and teamwork between WPI students and ACUC students were very productive, e-waste sites in both Ghana and Worcester were a huge help, and after testing

on the ground, local partners provided feedback which reshaped the design and created more impactful solutions.

The interactions between students and local partners are mapped out in Figure 9. Creating this people map helped show who was involved in the Stirling engine teams process and the types of interactions they had with one another. This information was collected through the meetings I had with the team and asking them who and how they have worked with the local partners. As seen in Figure 8, the WPI students interacted with every local partner and other stakeholders such as the Ghana Project Center Professors. Given the goal to co-design with local partners, it is best to have as many communication arrows flow between everyone involved in the process and Figure 9 is a good example of such well-rounded flow.

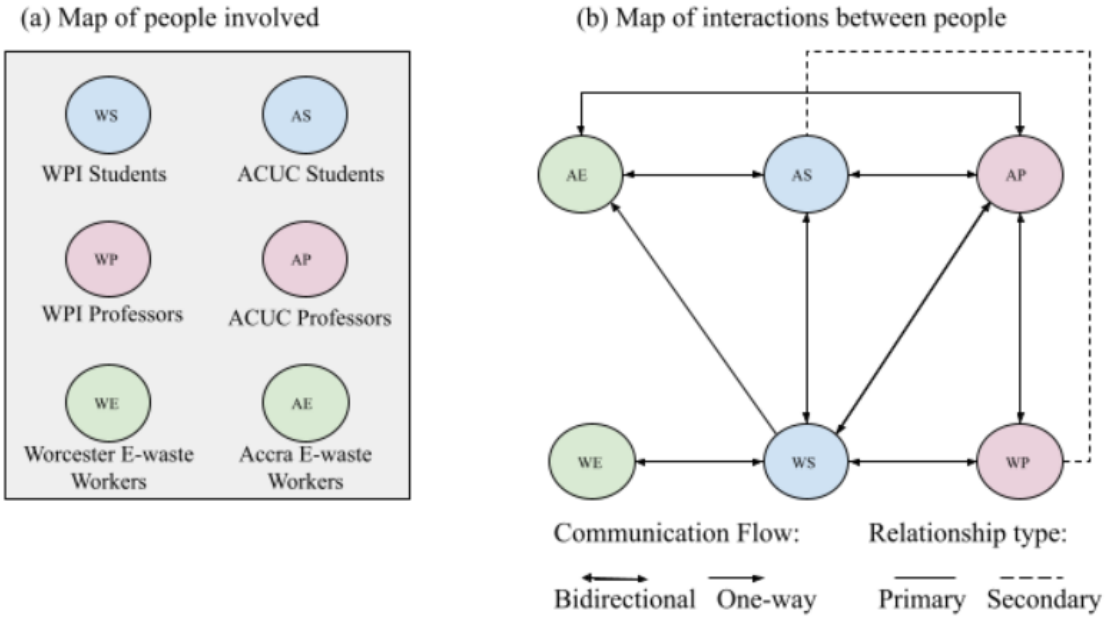

Figure 9: Stirling engine project people map

Lastly, the outcomes matrix in Figure 10 shows the various outcomes of interest for this specific project in terms of generative justice. The outcomes matrix includes both proximal and distal outcomes. Proximal being the short term goals and distal being the long term goals.

		Outcomes for:		
		Ghanaian Community	Ghanaian E-waste Workers	WPI Students & Professors (Smart Village Organization)
Proximal	**Desirable**	- Product can be used safely by any individual. - Community can charge cellphones using the engine.	- Ability to maintain the engine short term. - Learn different ways to utilize e-waste.	- Gain knowledge and experience in using reusable material for design and interdisciplinary work.
	Undesirable	- Community members do not take advantage or aren't aware of this resource.	- Lack of familiarity with how the engine works, and how to replicate it.	- Not working alongside Ghanaian partners.
Distal	**Desirable**	- Suits the long term needs of the community. - Creates business opportunities.	- Ability to replicate the engine using e-waste materials.	- Continued development of the engine for future projects.
	Undesirable	- Community members don't find this solution essential in comparison to other priorities.	- Difficult and expensive to replicate the design.	- The design team has career goals that are inconsistent with community goals. - Not having the community's best interest at heart.

Figure 10: Stirling engine project outcomes matrix

Given the COVID-19 pandemic and the inability to work on the ground, the WPI Ghana Project Center and students put in much effort into a co-design process that achieves generative justice goals. The Stirling engine team found similar difficulties to those experienced by the plastic recycling team, many to do with not being on the ground. Meetings with partners on the ground was crucial but hard to make happen due to the time differences, these meetings helped ensure everyone involved was on the same page and understood where the project was heading. This team stated that the were constantly exploring and communicating with the partners on the ground which informed me that the exploration step is not singular but it constantly occurring. Co-ideating with the partners on the ground was the most important step the team accomplished, especially because they were working hand in hand with the ACUC students and the project could not have been done without the e-waste workers in Ghana.

4.2.2: Case 2: Plastic Recycling Project Team

This project aimed to tackle the problem of rural plastic waste management in the Eastern Region in Ghana. In partnership with numerous local chiefs, this team developed an actionable plan to establish a regional recycling partnership to coordinate collection, transportation, and sale of plastic waste. To do this, they developed a co-design framework that governed the design process of their proposed system to ensure it is generativity just, culturally centered, and scalable. With these design principles established, they worked with entrepreneurs, local

partners, and other stakeholders to determine management, funding opportunities, and supply chain logistics. Ultimately, they provided a data-driven feasibility report outlining the necessary stakeholder contributions to ensure the sustainability of their project. This was followed by an extensive discussion on the lessons learned over the course of the design process, so as to better prepare future partnerships for the challenges inherent in successfully co-designing cooperative businesses.

As seen in the swimlane diagram in Figure 11, the plastic recycling team consisted of three stakeholders: WPI students, local partners including village chiefs and Ghanaian business entrepreneurs. The project idea was identified by the local partners, who brainstormed solutions with WPI students and provided feedback and insight before the WPI students went over any major steps.

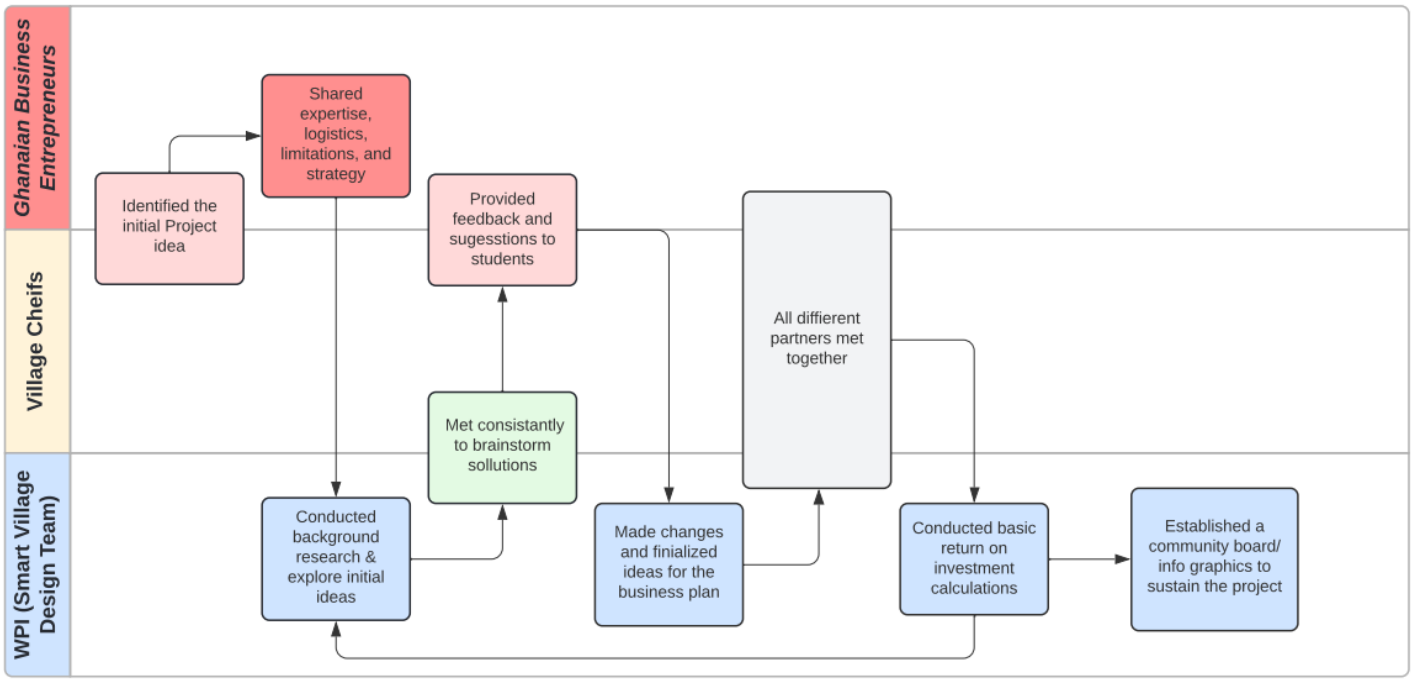

Figure 11: Plastic recycling project swimlane diagram

Similar to the Stirling engine team, the plastic recycling teams barriers were mostly due to not being on the ground and the facilitators were due to working hand in hand with local partners, which is shown in the PETT scan in Figure 12. The people map shown in Figure 13 shows that this team worked with a variety of partners including villages chiefs, the former Ghanian ambassador, and local business entrepreneurs. The team informed me that the meeting they had with multiple stakeholders at once was essential to the success of their project. Figure 14 shows the outcomes matrix for the plastic recycling team which shows their desired goals considering generative justice principles.

Factor	Barriers	Facilitators
People - Students (ACUC & WPI) - Village Chiefs (Denase, Batabi, Tumfa, Abompe) - Ghanaian Business representatives - Former Ghanaian Ambassador - Ghanaian community - Student who worked with the chief on a plastic project in Ghana before		- Brainstorming environment worked really well - Students and partners together reached reasonable solutions faster than assumed - Denase chief helped students get in contact with more local partners
Environments - Physical (WPI spaces) - Socio-organizational (WPI project center) - External	- Different time zone - Not being on the ground (distance)	
Tools - Knowledge - Communication platforms - Plastic Waste	- Limited ways of contact	- Readily available plastic in Ghana - Knowledge shared by village chiefs and business entrepreneurs was essential to the teams work
Tasks - Conduct research - Contact Partners - Brainstorm ideas - Data collection - Design solutions - Return on investment calculations - Implement/sustain solutions	- Short time frame	- After testing, solutions were completely reshaped and the process went more smoothly the second time
Interactions (between People, Environments, Tools, & Tasks) - WPI students met consistently with the Chief of Denase. - WPI students met with chiefs of Batabi, Tumfa, and Abompe - WPI students met with plastic business entrepreneurs - WPI students met with the former ambassador of Ghana to gain credibility - WPI students, village chiefs, and the former ambassador met all together - WPI students contacted ACUC students to make educational resources and running surveys - WPI students met with students who worked on plastic recycling projects before to gain insight	- Scheduling meetings (tasks) with different parties (people) all together on one platform (tools) is difficult	- Knowledge, information, and ideas (tools) are being shared between different parties (people) - Combined meetings with students, chiefs, Ghanaian ambassador, (people) are helpful and make sure everyone understands where the project is going (tasks)

Figure 12: Plastic recycling project PETT scan

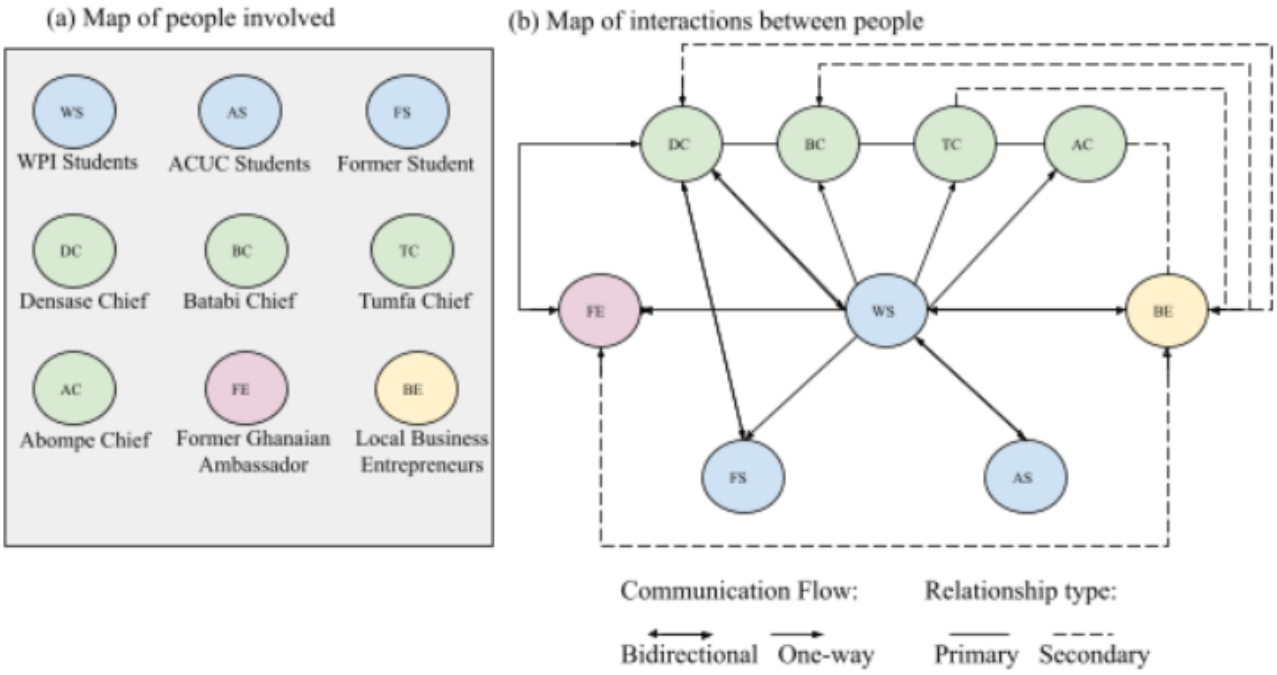

Figure 13: Plastic recycling project people map

		Outcomes for:		
		Ghanaian Community	Village Chiefs & Plastic Entrepreneurs	WPI Students & Professors (smart village organization)
Proximal	**Desirable**	- Utilizing available plastic waste for the benefit of the community.	- Ability to maintain the business plan short term. - Learn different ways to utilize plastic waste.	- Gain knowledge and experience in using reusable material for design and interdisciplinary work.
	Undesirable	- Only benefits certain people within the community.	- Inability to maintain the business plan.	- Not working alongside Ghanaian partners.
Distal	**Desirable**	- Suits the long term needs of the community. - Creates business opportunities.	- Establishing a joint board with different representatives who will sustain the project. - Utilize infographics made by students and educate the community about plastic waste.	- Continuation and development of the business plan for future projects.
	Undesirable	- Community members don't find this solution essential in comparison to other priorities.	- Conflict within the different business partners.	- The design team has career goals that are inconsistent with community goals. - Not having the community's best interest at heart.

Figure 14: Plastic recycling project outcomes matrix

During my discussion with the plastic recycling team about their process they brought up that step two - explore - in the initial design process shown in Figure 6 was the most useful. This was because the students are somewhat outsiders when it comes to the community especially working remotely, so they found communicating with the partners on the ground essential. They found that they went through the whole process many times, they would work with their partners, gain insight and feedback then go back and change the work. This team found the distance due to working virtually a setback to the success of their project during the co-ideate and co-create steps. Solutions took more time to complete because of the distance. They have also brought up that technology was a big set back as well, that making group calls work was very difficult. They found that the people on the ground used different platforms of communication and it was hard to get a hold of all the stakeholders at once. However, when meetings did happen they were very helpful and brainstorming went really well. Meetings were limited, and the students could not communicate with all the different stakeholders as they wished to. This team did not need to acquire funding as a complete step, they stated that their projects goal was to create something that the community can then use to generate value which meant funding was not a major step in their work. Overall, funding and exploring were not singular steps in either projects and the co-ideate and co-create steps were the most important steps to achieve generativity just projects.

4.3: Revised Co-Design Process

Utilizing the SEIPS methodology and depth and breadth levers, I have identified a complete system that should be put in place to ensure generative justice goals are met. This is because the process itself is not the only thing affecting what comes out of it and in order to achieve the generative justice goals, there is a need to take into account the system as a whole. This system consists of three main elements: the reframed goals and desired outcomes, the process, and the work system.

4.3.1: Reframed Goals and Outcomes

The goals and desired outcomes of the new process have been identified in previous chapters in this paper. The goal of achieving generative justice through co-design means the smart village organization needs to play an empowering role and work with the community on creating projects. There should not be any power balance or assigned roles such as the “helpers” and “receivers”. Everyone in this system is working together towards one goal. Ideally, the community members are completely empowered to sustain these projects after the smart village organization moves onto another project.

4.3.2: The New Improved Process

Figure 15 shows the improved finalized design process map. Although these steps do no differ that drastically from the traditional process, the system around the process is what helped accomplish the desired goals. This process would be a success for many projects but if the steps are not surrounded by the right people, environments, motivations and more it would not accomplish generative justice goals.

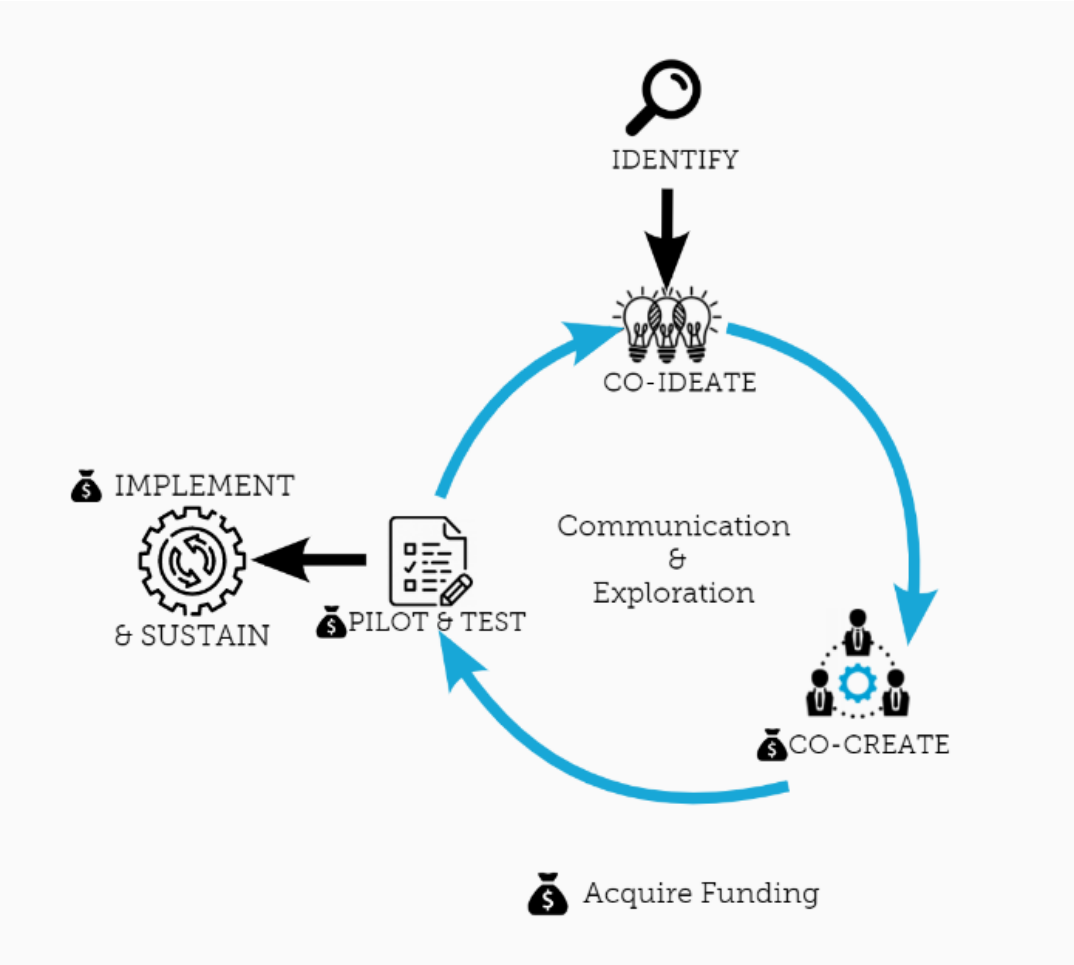

Figure 15: Improved co-design process

I used the two case studies to gain insight on what worked well in the initial idealized co-design process and what still needed improvement in order to map out the final improved process shown in Figure 15. The first step both teams did was very clear, identifying the problems was essential to start any project. This step was also the first step in the traditional design process, however the motives behind it are different now. The reason identifying the pain points is needed within a co-design process is to listen to the community and allow them to identify what they need and want. During this time and consistently the team should be exploring while communicating with partners best solutions, the culture, the available resources and more. This

step is always happening and is necessary for every step, in order to be a true co-design process. Funding is also something that is not always needed for every project to be successful. WPI teams relied on the university resources so they did not need to acquire funding, however if they did, it would have been incorporated in any of the co-create, testing, or implementation steps. Co-ideating is the next actual step after identifying the problems, co-ideating looked different in these projects due to the lack of contact with the partners given the pandemic. However, the teams worked around this by brainstorming with their partners when they had the chance to and if it was not possible to get a meeting set up in time, they would gather feedback and insight on these ideas as soon as they could and would not go forward with any plans without their partners approval. Co-create is the third step, this was done by teams at WPI and the teams on the ground simultaneously creating the solutions. For example, the Stirling engine team were building the suggested engine as the ACUC students were building it on the ground. This way not only are the partners able to understand and learn how the product works in order to provide insight and feedback but they are able to replicate it in the future when the WPI students complete their projects. The fourth step is to pilot and test these created solutions, this is ideally tested on the ground by the partners and if not viewed as helped or a success in the community's eyes then the process is reiterated and we are back to the co-ideate step. This reiteration process was proved successful by both teams. Although they did not reach the testing step in their projects, they were able to gather enough feedback and do basic calculations on the success of the solutions in order to reiterate when needed. Lastly, all these solutions will be implemented and the goal is for them to be sustainable. Generative justice and co-design if done correctly work on ensuring projects are sustained through the community especially because they are the experts on these projects and can work on making them grow.

4.3.3: The Work System

In order to achieved reframed goals through the improved process, it is important to create the right work system surrounding it. This includes the people, their interactions, the environments, resources, and the tasks taken upon the different stakeholders involved. It is important that everyone involved in the process is aware of the reframed goals and how that will affect their work. The motivation behind what problems are chosen to work on and who chooses these problems is a big change compared to the traditional design process. This work is highly dependent on the Ghana Project Center, because they oversee assigning projects to students and are in most contact with local partners on the ground.

Specific recommendations for each element of the work system include:

- Tasks: (1) It is important to ensure teams are consistently communicating with their partners. This is easier said than done especially when working remotely in two different countries. However, this can be accomplished through the Ghana Project center by: (a) Planning early methods of communication with WPI students and local partners, gaining early access to

contact information of partners ensures that co-design is being implemented from the get-go of the projects. (b) Ensuring the partners are the ones coming to the WPI project center and not the other way around. (2) Another suggestion would be making sure the local partners are supported after the completion of the projects in order to sustain and continue the work on their own.

- Tools: (1) Ensuring WPI students have access to similar tools as those on the ground to get the most accurate results. For example, the Stirling engine team struggled with using e-waste sites from Worcester because they do not completely represent the material found in the e-waste site in Ghana. (2) Being informed that local partners use different communication apps than those used by WPI students was a helpful start for WPI students.

- People: (1) The Ghana Project Center needs to ensure there are a sufficient number of local partners who can work with students on projects every step of the way. (2) Continue the preparation before the start of the projects such as learning cultural differences, local language, and more. This is helpful even in a remote setting because it allows students to know how to approach meetings with partners virtually. (2) Ensuring the goals of generative justice and co-design are aligned with all the different stakeholders.

- Environment: (1) Ensuring there are people on the ground who are in charge of data collection especially when students in Ghana. For example, it was difficult for the Stirling engine team to test their engine in Ghanian temperatures and needed access to temperature data from partners on the ground. (2) Support mechanisms like the weekly ground progress reports and class discussions were helpful.

Chapter 5: Conclusion and Recommendations

Smart development is a movement that has fraudulently branded itself as a way to make the world a better place. It has been used as a tool for more privileged nations to gain economic growth and power. Although it is on a journey of progressing and taking into account the quality of life of the developing nations, there is still a long way to go when it comes to erasing its history and impact of being a postcolonial tool to colonize nations in the name of 'helping' them. WPI Ghana Project Center is wary of this issue and is working towards changing the intended goals for these types of projects and co-designing with the community to achieve generative justice goals. In 2022, seven WPI teams worked on developing smart village projects in Ghana, however the design process to guide their was not formally defined. Traditional development processes for smart villages prioritized the needs of the corporations involved and viewed villagers needs as secondary.

This project focused on developing a new design process based on co-design principles in order to create smart villages that are self-sufficient and self-sustained, and that generate value for those in living in the community. A continuous improvement approach was used. After evaluating the traditional design process and suggesting an initial improved process, I used two projects in the Ghana Project Center as case studies to understand what was working well and what needed to change. Finally, an improved process was suggested that consists of five major steps: identify, co-ideate, co-create, pilot and test, and lastly implement and sustain. These steps are crucial to the success of these projects but achieving the desired goals requires looking at the system as whole. The work system included the people, environments, tools, tasks and their interactions. Defining aspects of these work system components alongside the new co-design process can support the achievement of the desired generative justice goals.

Finally, I would recommend addressing several aspects of the work system to support the design process and the overall goal to achieve generative justice. In particular:

- Tasks: Constant communication between stakeholders is key. This can be done by early planning of communication methods and gaining access to contact information of local partners before the start of the project.

- Tools: Gaining access to similar tools as those on the ground is important in ensuring the designs created are successful in the local environment.

- People: Having the right people on the ground is the first step to success. It is also important students are learning about cultures and language differences before starting their projects. Also, ensuring students understand the non-western design methodologies.

- Environment: In a virtual setting it is important to acknowledge the different environments that the designs will be implemented in which is why having people in charge of data collection on the ground is crucial to the success of these projects.

Many of these recommendations would be much easier to implement the Project Center was working on the ground in Ghana. In conclusion, the new system and process focused on co-design with concrete steps to achieve generative justice can be used by future project teams.

Industrial Engineering Project Reflections

Design Process

Engineering design is the process of devising a system, component, or process in order to meet desired needs and specifications or in this case, generative justice goals. Typically, this evolves identifying opportunities, developing requirements, performing analysis, generating multiple solutions, testing and evaluating solutions against requirements. The goal of this project was to create an improved design process for project teams working with the Ghana Project Center, addressing co-design and generative justice methodologies. This was achieved by exploring the typical design process of developing smart villages in developing nations and addressing the gaps in which generative justice goals were missing. After extensive co-design and generative justice research, an initial new design process was mapped out. Two case studies were used to evaluate the initial improved design process, changes were applied, and finally the improved design process was presented. This design process is intended as a template for similar projects in the future.

Project Constraints

There were some constraints considered in this project, some due to the nature of the projects involved and others due to difficulties that emerged from the COVID-19 pandemic which did not allow the project teams to travel to Ghana. The biggest constraint I would say for this project was the inability to work on the ground, especially because this project was focused on co-design and co-design is very hard to achieve working remotely. Many of the teams I evaluated also found it difficult to contact our Ghanaian partners on a regular basis due to time differences, communication platform preferences, and different commitment expectations of students and stakeholders. Observing the interactions and conversations between students and stakeholders was an important aspect of this project that was not as easy to achieve to due the nature of working virtually. As everyone has been doing in the past two years, we have worked around these constraints well and adapted to the time differences and communication habits of those on the ground. The project overall sought to incorporate the goals of generative justice and specifically recognizing the importance of the social aspect in a project such as mine, these constraints did play a role in the design process developed.

Acquiring New Knowledge

There were many aspects of this project that I did not learn in my industrial engineering coursework. In this project I utilized many industrial engineering tools such as SIPOC diagrams, swimlane diagrams, SEIPS models, and more. Although I have learned how to use some of these tools in a business setting, I have never had practice using them in a more social problem. I worked around this by trial and error, looking at the situation from more of a business point of view and breaking things down into more understandable terms. A set of tools I utilized that I have never been introduced to before were the SEIPS models such as the PETT scan, people

map, and outcomes matrix. This set of tools was important in evaluating the two team projects used as case studies. My advisor Professor Sharon Johnson was a huge help in introducing me with these tools and provided me with the resources in order to learn how to use them.

Teamwork

Although this was a solo project, the work done would not have been accomplished without collaborating with the IQP and MQP teams involved in the Ghana Project Center. I have learned to be more vulnerable with my advisors and reach out for help with questions when needed, especially given that I had no teammates to support me throughout this project. This project relied a lot on the six team projects and the work they were doing, specially the two teams taken as case studies for intensive evaluation. I utilized our weekly class meetings with all the teams and advisors in which we would present a progress report to inform the class on the work done so far for each project. During my presentation I informed the project teams that I would be contacting them to schedule meetings to learn more about their work in detail. I utilized When2Meets and outlook calendars to set up meeting with them and made sure I was invited to any meetings project teams had with local partners. This ensured I was not only learning about the teams' interactions with partners through asking questions, but by observing the actual meetings occurring and the types of interactions between them.

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