



NRCP
RESEARCH JOURNAL

Full Paper

Social Development in Mining Technology Transition: The Case of Community-led Non-Mercury, Non-Cyanide Gold Extraction Method (CLINN-GEM) in Davao de Oro, Philippines

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This social development research theorizes the process of technological transition through a social development lens. This single case study is exploratory and descriptive which employs qualitative methods in data gathering and analysis. The results revealed that Community-led Non-Mercury, Non-Cyanide Gold Extraction Method (CLINN-GEM) technology transition process follows a technology innovation cycle that starts with documenting what the people know about mineral processing and establishing methods to systematize the process (research and development) towards rolling it back to the people (adoption). During the transition, restructuring organizations and physical, cognitive, and social systems were made to effect change in knowledge realms and the social conditions of the community. The social development perspectives highlighted during the transition process focused on transformative change, progressive, multidimensional and multifaceted, interventionist, with the goal of improvement of people's well-being. Further, the technological transition generates outcomes and impacts which are heavily dependent on the following factors: clear vision and goals; firm commitment and available resources of actors, efficient technology for sustainable operations, and policy formulation enforcement. The results of this study have conceptual implications in understanding social development in technological transitions and practical implications on sustainable technological transition. Lastly, the author recommends actions to ensure successful technological transition and further studies to better understand the research topic.

Keywords; *Social Development; CLINN-GEM Technology; Small-scale mining; Technology Transition*

Article history

Received : February 3, 2023

Revised : September 20, 2023

Accepted: February 11, 2024

Introduction

Mining is a global industry and is often located in remote, ecologically sensitive, and less developed areas that include many indigenous land and territory. It can create jobs, spur innovation, and attract investments and infrastructure at game-changing scales over extended periods. If managed poorly, it leads to various challenges, such as environmental degradation, displaced populations, inequality, and increased conflict (Lewis, Flynn, Davidson, Sachs, Sonesson, Maennling, Toledano, Halling, Barredo, Peachey, 2016). The small-scale mining industry in the Philippines is confronted with several challenges including formalization, issues resulting from low technology, poor practices, processing, and marketing or geo-prospecting (Hentschel, Hruschka, & Priester, 2003; Hilson & Pardie, 2006), health and occupational problems (Asirot, 2000; Colina, 2008; Decena, 2016) while their communities suffer from the pollution of rivers and the destruction of agricultural lands, mangroves and coral reefs (Baggo, 2015; Doyle, Wiks, & Nally, 2007). These conditions exacerbate poverty compelling small-scale miners to exploit limited resources further. This cycle continues and results in the "poverty trap" (Hilson & Pardie, 2006).

To answer the call of providing alternative technology for small-scale miners which use environmentally friendly and non-hazardous methods of gold and/or copper extraction (Gamba, 2019), the University of the Philippines Department of Mining Metallurgical and Materials Engineering (UP DMMME) and the Department of Science and Technology (DOST) through the BetterMine Program of the Environment and Infrastructure track of the Engineering Research and Development for Technology (ERDT) developed the Community-led Integrated Non-Cyanide, Non-Mercury Gold Extraction Method (CLINN – GEM) in 2015. This technology is an alternative method to amalgamation and cyanidation in the recovery of gold (DOST XI, 2015). This project also led to the establishment of the Integrated Gold-Copper Mineral Processing Pilot Plant in the following four areas in the Philippines: 1) Sitio Basil, Barangay Gumatdang, Itogon Benguet in Cordillera Administrative Region (CAR); 2) Barangay Sta. Rosa Norte, Jose Panganiban, Camarines Norte (Bicol); 3)

Barangay Del Pilar, Cabadbaran City (CARAGA); and, 4) Barangay Katipunan, Nabunturan Compostela Valley now Davao De Oro (Davao Region).

The goal to address environmental problems and move toward long-term sustainable development in mining communities is a significant challenge for today's global world (Dubinski, 2013). Technology innovations require the transition and restructuring of unsustainable systems that underpin societies to steer development in a more sustainable direction (Kemp & Loorbach, 2003). Thus, this social development research theorizes the process of technological transition through a social development lens. It attempts to describe how social development perspectives apply to technological innovation transition in mining communities. In light of understanding social development in technological transitions, this study aims to describe the process of technology transition in small-scale mineral processing brought about by the CLINN-GEM technology, identify what social development perspectives were applied are carried out in this technological transition, and draw lessons and theoretical constructs from the experience of technology transition in mining communities

Methodology

Epistemologically, this study was drawn from the critical social science paradigm. According to Neuman (2014), critical social science is an inquiry that goes beyond surface illusions to uncover the real structures in the material world to help people change conditions and build a better world for themselves.

The study uses a single case study approach to explore and describe the general characteristics and patterns of technological innovations in small-scale mining communities. It adopted qualitative methods in data gathering and analysis.

Ethics Statement

The research respondents are the different stakeholders of the community which were purposively selected based on the selection criteria. The respondents include small-scale miners, local government officials, members of different community organizations, especially those who initiated and implemented the field testing project, and community members. The respondents were classified into three groups, the key informants,

FGD Participants, and the PRA Participants. The research instruments used in this study include a key informant interview guide, workshop design, observation checklist and focus group discussion guide. Lastly, to ensure the protection and consent of the participants, a prior informed consent was secured prior to data gathering.

Results and Discussions

The CLINN- GEM Technology

CLINN-GEM Technology Background and Features

The CLINN-GEM technology is a systematic articulation of the small-scale miners' mineral processing methods. It is anchored on gravity and flotation techniques which are commonly used by small-scale miners. It was developed by UP DMMME to answer the call of providing alternative technology for small-scale miners which use environmentally friendly and non-hazardous methods of gold and/or copper extraction (Gamba, 2019). This technology is undergoing field testing in Gold-Copper Integrated Mineral Processing Pilot Plants which were established in four regions in the country: 1) Sitio Basil, Barangay Gumatdang, Itogon Benguet in CAR; 2) Barangay Sta. Rosa Norte, Jose Panganiban, Camarines Norte (Bicol); 3) Barangay Del Pilar, Cabadbaran City (CARAGA); and 4) Barangay Katipunan, Nabunturan Compostela Valley (Davao Region).

Aside from gold, CLINN-GEM can recover other valuable minerals such as silver, copper, lead, zinc, and others. The CLINN-GEM technology has six features: size reduction circuit (crushing and grinding), enhanced gravity concentration circuit, flotation circuit, hypochlorite leaching, staged precipitation circuit, tailings disposal, and wastewater treatment facility, and analytical (Fire Assaying) laboratory (UP-DOST, 2019). The features are described as follows:

First is the size reduction circuit (crushing and grinding). The crushing circuit is comprised of a jaw crusher, vibrating screen, double roll crusher, and fine ore bin. Crushing is undertaken to reduce the size of the ores such that grinding can be carried out until the minerals are liberated from the gangue. The grinding circuit is comprised of a ball mill and a hydrocyclone. With the use of a belt feeder, crushed ore from the fine ore bin is transported to the ball mill spout. Ball mills are used in the grinding of ores and other materials. The ball mill is in a closed circuit with a hydrocyclone, a piece of classification

equipment that enables the separation of coarse and fine particles in the slurry.

Second is the enhanced gravity concentration circuit. This circuit is composed of two types of gravity concentrators, the Falcon SB 400 concentrator, and the shaking table. The Falcon SB400 concentrator is used for the recovery of valuable minerals, while the shaking table enables the separation of light and heavy minerals by using a flowing film of water and a table vibrating longitudinally.

Third is the flotation circuit. This circuit uses self-aerating mechanical flotation cells and reagents such as collectors, frothers, and pH modifiers to separate valuable minerals from unwanted minerals (gangue).

Fourth is the hypochlorite leaching and staged precipitation circuit. This circuit is comprised of leaching tanks and precipitation tanks. The leaching tank is used for the chlorination process where sodium chloride, hypochlorite, and hydrochloric acid are added to the concentrate. Gold and silver tanks are connected in a series. In the gold precipitation tank, sodium metabisulfite and ascorbic acid are added to produce a gold precipitate, which is then smelted using a surface with a working temperature of 600-700 °C. Meanwhile, the silver precipitation tank contains the clear liquid produced in the dewatering of gold and will be added with reagents to form a silver precipitate.

Fifth is the tailings disposal and wastewater treatment facility. The tailings disposal and wastewater treatment, also called tailings storage facility (TSF), is an essential feature of the pilot plant to protect the environment because it is where hazardous components from the tailings are removed before being discharged permanently. The TSF includes wastewater treatment with a tailing settling pond. The wastewater treatment compartment is where heavy metals are removed from wastewater generated in the extractive metallurgy area. The removal of heavy metals is by adsorption using coco peat and zeolite. The wastewater treatment compartment is divided into three (3) sub-compartments to allow treatment in 3 stages. The tailings pond allows solids to settle and produce clear water that can be discharged to the nearby river.

Lastly, the analytical (Fire Assaying) laboratory. The laboratory area contains equipment for analytical

tests. The oven, furnace, chipmunk crusher, and disc mill pulverizer are located inside the Fire Assaying room.

The CLINN - GEM Process

Figure 1 shows the process flow of CLINN GEM (UP-DOST, 2019). Fresh ore is loaded into the jaw crusher and roll crusher before grinding. The crushed ore is then loaded into the ball mill for grinding via a conveyor belt. The slurry coming from the grinding circuit is then pumped through the Falcon gravity concentrator. The concentrate coming from the Falcon concentrator is collected and concentrated using a shaking table.

At this stage, visible free gold is collected for direct firing. The operations for each section in the crushing-grinding-gravity concentration circuit may run simultaneously. The CLINN-GEM method can process the ore in approximately twelve hours.

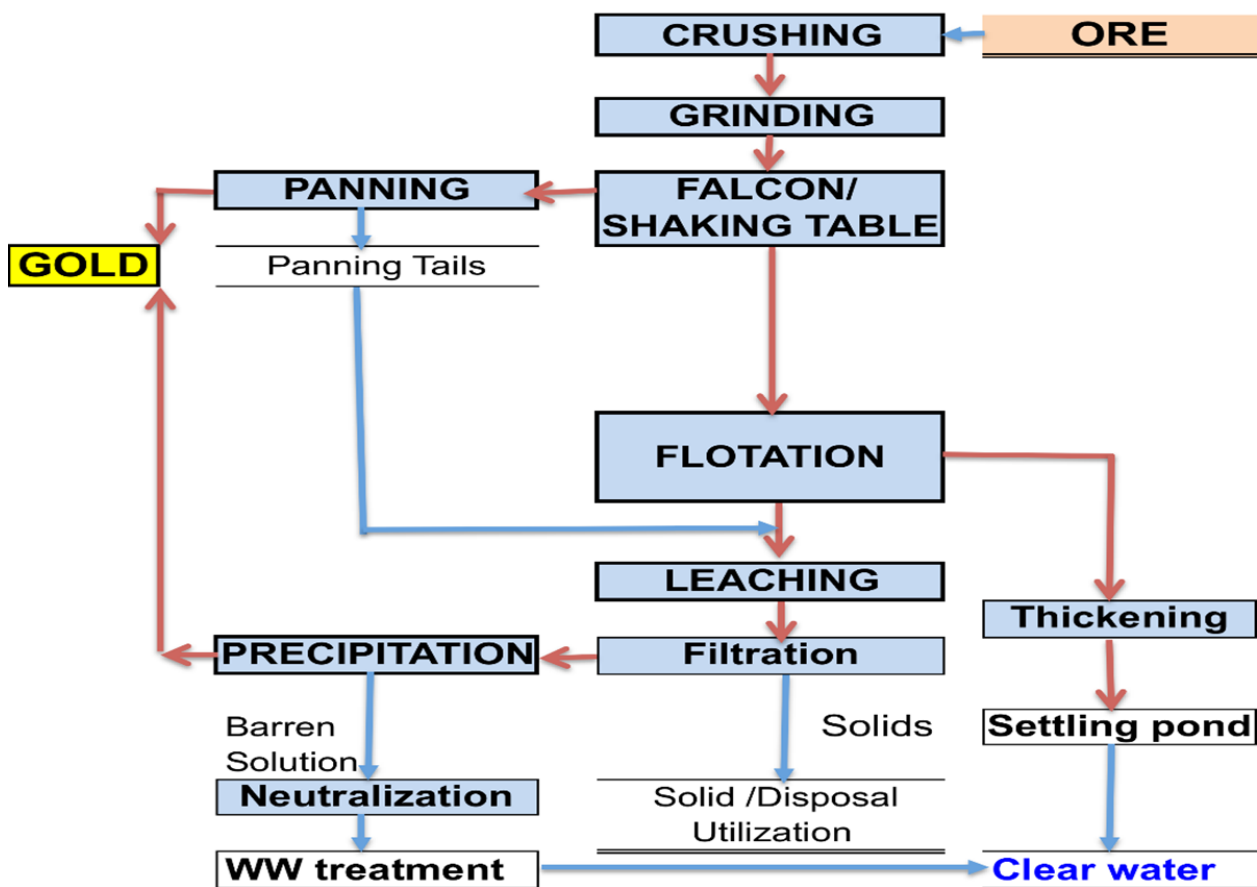


Figure 1. CLINN-GEM Process Flow

Note. This figure was adopted from UP-DOST (2019). Field Testing of the Integrated Gold-Copper Mineral Processing Pilot Plant in Compostela Valley Terminal Report.

The tailings from the gravity concentration are thickened before getting pumped into the flotation circuit in batches of 0.5MT each. Flotation concentrates coming from the re-cleaner cells are collected and set aside until all flotation batches are completed. A mixture of calcium hypochlorite and sodium chloride is first fed into the oxidation/leaching tank.

The solution is mixed thoroughly to achieve homogeneity before adding it to the final flotation

concentrate and shaking table middling. After four hours, calcium hypochlorite replenishments are added and after three hours, the oxidation/leaching tank is emptied. The mixture goes to the Filter Press for dewatering. The pregnant solution, which contains the leached gold, is collected in the precipitation container via a launder. Sodium metabisulfite is added to the precipitation container to precipitate the gold. The solution is mixed thoroughly for at least five minutes. After this, ascorbic acid is added. The solution is again

thoroughly mixed for at least five minutes and left for about two hours overnight to precipitate the gold. After that, the solution is filtered using the pressure filter to separate the gold precipitates. Zn dust precipitation follows, and the entire process ends with filtration. The gold precipitates undergo purification using a blow torch to produce the final product – a gold bead.

Lastly, one of the most important contributions of CLINN-GEM Technology, which is absent in traditional technologies, is the neutralization of wastewater. The solid residue is washed with water before discharging to the tailings settling pond. The washings and barren solution are placed in the neutralization tank to neutralize the pH before getting discharged to the wastewater treatment compartment. The solution flows through the coco peat-zeolite layer. The treated water at the bottom goes to a holding area (empty compartment). When this compartment is full, it overflows to the second compartment for the second stage of treatment. The treated water from the second stage proceeds to the third compartment and the final stage of treatment. The treated water from the third stage, together with the clear water, is discharged into the river (UP-DOST, 2019).

The CLINN-GEM Process of Transition and its Challenges

Technology innovations such as CLINN-GEM undergo transition, from development to adoption, and even retirement. At present, CLINN-GEM technology is being rolled out to selected small-scale mining communities through the implementation of the field-testing project.

The Field Testing Project Framework and Activities

The field-testing project is a research and development project, and like other

development projects, its implementation is guided by a framework, which entails a combination of community and technical activities. The project framework (see Table 1) involves five phases: pre-deployment; deployment; commissioning; operation and management; and, turnover (DOST XI, 2015). Each consists of different activities involving various stakeholders.

The implementing agency, DOST-XI, was responsible for the pre-deployment and deployment phases with supervision from the UP-DMMME team. UP-DMMME provided the technical data and specifications for all the activities under the said phases and conducted workshops for the project technical staff directly involved in the project. The UP-DMMME took over during the commissioning phase. Meanwhile, after the parallel testing, UP Diliman and the stakeholders decided to suspend the operations and management phase to provide ample time for further study on more variability and optimization of results. Despite the operations' suspension, the Board of Advisers (BOA) members decided to proceed with the turn-over phase. In the turnover phase, the PLGU was responsible for the operations of the mineral processing plant under the supervision of DOST XI and UP-DMMME. Other stakeholders, like Compostela Valley State College (CVSC), Municipal Local Government Unit of Nabunturan (MLGU Nabunturan), Barangay Local Government Unit of Katipunan (BLGU Katipunan), and Nabunturan Integrated Miners Development Cooperative (NIMDC), collaborated in the activities initiated by the said agencies.

Table 1. The Field-Testing Project Framework and Activities

| Pre-deployment | Deployment | Commissioning | Operations and Management | Turn - Over |
|---|--|--|--|---|
| <ul style="list-style-type: none"> • Consultation, orientation, and organization of stakeholders (PMC) • Public consultation and information dissemination • Benchmarking activities • MOU Signing (understanding to establish the Plant) • Conducted coordination meetings with stakeholders • Ocular inspections and surveys • Secured permits, clearances, and certificates • Conduct groundbreaking ceremony • Procurement of mineral processing building permit • Procurement of equipment | <ul style="list-style-type: none"> • Conduct baseline studies Value Chain and Environment Impact Assessment • Construction of the facility • Employment of the locals • Installation of equipment • Selection and training of operations group* • Coordination with NGA and the community • Community preparation and permit installation for 3-phase electric connection • MOU and crafting for the commissioning of the mineral processing plant • Conducted CSR activities – outreach tree planting, livelihood training | <ul style="list-style-type: none"> • Equipment testing with stakeholders PMC and the suppliers • Equipment Testing with DOST TWG • Commissioning with UPD • Hands-on training of the operations group • Fine-tuning • Parallel testing | <ul style="list-style-type: none"> • After the parallel testing, the PMC decided to suspend the operations but continuous field testing is going on | <ul style="list-style-type: none"> • The signing of MOA for Turn-over • Hand-over of manuals and SOPs to PLGU • Project education and information Campaign |

Pre-Deployment Phase

The activities in the pre-deployment phase are primarily characterized as social/ community and technical preparation. They directly involved the community, major stakeholders, and the project staff. During this phase, the barangay residents raised the following major concerns such as doubt, noise, possible land grabbing and robbery, and the need to be vigilant of its process since mineral processing is very quick.



A. Signing of Memorandum of Agreement



B. Ground Breaking Ceremony

Figure 2. Pre-deployment activities

Deployment Phase

The activities during the deployment phase consisted of research, capability building, community organizing, and community mobilization. Most of the activities directly involved the residents of Barangay Katipunan and the project stakeholders. However, the project implementation was faced with two significant delays. The first one was the delay in the procurement of materials and the construction of the plant. Since the project is government-funded, the purchase of supplies and materials has to undergo government procedures. Bidding procedures and the

highly bureaucratic procurement system were identified to have primarily caused the delays. Weather conditions also contributed to the delays as construction began in the rainy season. The other significant delay was the payment of salaries of the construction workers whose pay depended largely on their accomplishments which were aggravated by the delays in procurement. Originally, the construction was targeted to finish in six months from August 2016 but it lasted for a year. On August 2018, the deployment phase ended when the construction of the facility was over and all equipment was installed.



A. Conduct of Technical Training for the Operations Group



B. Conduct of Community Training for the Operations Group

Figure 3. Deployment Activities

Commissioning Phase

The activities in the commissioning stage were divided into three phases: 1) pre-commissioning and operational testing; 2) Start-up and initial operation; and, 3) performance and acceptance testing. After the commissioning, the residents raised concerns about the efficiency of the technology since they have not heard of it before.



A. Preparation of Equipment for Operation



B. Preparation of Equipment for Operation

Figure 4. Commissioning Activities

Operations and Management Phase

The operations of the mineral processing plant are suspended because of the difficulties encountered with ore variability. Chemical formulations prepared by the implementing team were not suitable for Lead and Zinc rich ores – the characteristics of ores used during the parallel testing. As a result, the

flotation process marked a low gold recovery result. With this, the stakeholders decided that continuous tests need to be further conducted to optimize the gold recovery.

Turnover Phase

On June 28, 2019, UP Diliman as the owner of the technology granted a limited, royalty-free, non-commercial, non-exclusive, and non-assignable license to the DOST XI and the Provincial Government of Compostela Valley, now Davao de Oro (Gamba, 2019 & MOA for turn-over, pp. 3-5). The license granted to DOST XI provides the rights to construct and assemble a Pilot Plant located at Barangay Katipunan, Municipality of Nabunturan, Compostela Valley in the Davao Region while the license granted to the provincial government provides for the rights to use the CLINN-GEM, including its hardware, software, procedures, and modules for the fulfillment of their responsibilities in the project only. This activity symbolizes the formal turnover of the mineral processing plant facility to PLGU Davao de Oro.

Challenges and Issues

With the various activities conducted, several challenges have arisen including 1) the optimization of the technology; 2) resources for the operation of the mineral processing plant; 3) the promotion of the technology; and, 4) policy implications of the new technology.

Optimizing the technology is the primary challenge that confronts PLGU and DOST XI. The need to optimize technology has two concerns. The first is to fully characterize all gold ores in the province for higher gold recovery, and the second is to recover copper using the CLINN-GEM technology. On gold recovery, the respondents recalled,

"We have four parameters that are being tested during the parallel testing, usa environment cost, operating cost, processing time ug recovery. So, sa environment well okay, kana savoras okay ug sa gasto okay, mas barato. Naay gamay ra nga chemical mao barato pero naigo ta sa recovery" (Four parameters are tested in the parallel testing and these are environmental cost, operating cost, processing time, and recovery. The plant is doing well in the environment, time, and operating costs. We use only a few chemicals. But we were hit badly in terms of recovery).

(Jessie, Plant Supervisor, KII Transcript lines 849-850, page 20).

"Ang problema unsaon pagpadako sa recovery, mao nay problema" (The problem is how to increase the recovery). (Yano, NIMDC Officer, KII Transcript line 631, page 15).

"Ang assumption nato diba first ang amalgamation 40-50% or 30-40%. So we have surpassed that recovery na since we are at 57%-80% na. Gina work out pa nato na maka compete ta with the cyanidation at around 90% na level" (We assumed that the recovery rate for amalgamation is at 40 to 50 percent or 30 to 40 percent. We have surpassed that since we're already at 57 to 80 percent. We're still working to compete with cyanidation, which recovery is around 90 percent). (Jessie, Plant Supervisor, KII Transcript lines 844-846, page 20).

While the result of the parallel testing shows that gold recovery through the CLINN-GEM is faster in terms of operating time, cheaper in terms of operating and environmental costs, and higher in terms of gold recovery using gravity concentration, its gold recovery using the flotation process fails to surmount gold amount recovered using cyanidation. This was attributed to the following: 1) higher consumption of cyanide, which is ten times higher than normal; and, 2) the presence of lead (Pb) in the ores that act as catalysts in the cyanidation process. These difficulties led to the suspension of the leaching process for further analysis.

Gold recovery is a primary concern for small-scale miners who rely heavily on operations for subsistence. One of the Key informant said *"Ang environmental cost justified man but dili jud na masabtan sa ordinaryong minero ang mubo nga recovery. Sa ato okay rana para saato kung moistorya lang ta pero at the end para sa tawo nga kaon ang gisaligan wala oi, dili nato na pwede ikombinsi, kana man jud kay kaon man jud at the end of the day"* (Environmental cost can be justified to ordinary miners but low recovery can't be. We can discuss preservation in our level, but how do we explain that to those who rely on recovery for their survival? How will they eat everyday?). (PLGU Officer JJ, KII Transcript lines 131-134 pages 3-4).

Another concern to optimize technology is the recovery of copper. The recovery of copper and other minerals is a distinguishing feature of

the CLINN-GEM. The PGLU, DOST XI, and other stakeholders are interested in this because gold mining operations in the province have slowed down and some miners have accumulated tailings that may contain valuable copper. Copper, however, has not yet been recovered from the tailings. The respondents, specifically the small-scale miners look forward to the optimization of the CLINN-GEM technology which is expected to aid in gold recovery. According to one of the Key informants:

"kung ang purpose man gud niya kay kuan gud gitawag gud sya ug gold-copper. Kung makaproduce man lang ug ma-separate man lang ang copper, mahalina man ang copper. Kay daghang custom milling karon nga ma-separate ang copper kay – ma-export pud nimo, so mao ni ang usa pud sa among gitan-aw ngadunay plus ba. Dunay plus factor niya pero tinuod nga gamayg recovery pero gimong tan-awon dunay plus ngano man kung ma-recover ang copper kay mao man lagi ang type pud nga ana gold-copper man, okay ra kayo murag makuntento ang mga tawo kay daghan mang ang mo custom milling karon diha ug ingon-ana" (The plant recovers both gold and copper. If only it can do separate recoveries, then copper can still be recovered and eventually sold. A number of miners will customize milling to recover copper. Copper can be sold for export. The miners will be contented). (NIMDC Officer Yano, KII Transcript lines 642-652, page 15).

The challenge of optimizing technology has caused rumors to spread in the mining community even before the results of the parallel testing come out. The ComDev office continues to await the results before conducting information dissemination.

"Wala pa jud mi nag conduct ug official information dissemination, kay kami sa ComDev department kay ginahulat pud namo ang result gyud. Para proper jud and fully documented gyud." (We at the ComDev department have not yet conducted official information dissemination activities for we're still awaiting the results of the test. We need to follow proper procedure). (ComDev Officer Gigi, KII Transcript lines 1383-1385, page 34).

Another concern raised during the interviews is the promotion that has been done about the technology. The project staff and partner stakeholders specifically the miners expressed that they are unconvinced with the technology's efficiency as

shown in its recovery rate. This makes them hesitant to promote the technology. The respondents said,

"After sa mga promotions na atong ginabuhay so mas open sila for new development sa processes, yun nga lang nagaexpect sila ug good result. Although gina consider nila ang environmental aspect na ma resolve or ma taban gsa technology, pero more on gyud sila sa economic viability, kumbaga if it will not work economically inspite na maka resolve sya sa problem sa environment. Kung dili siya mo equivalent sa existing technology ang iyang recovery murag dili sila ready to accept. Unless siguro e explain at least duol sa recovery sa existing technology." (The people are now more receptive to technology after participating in promotional activities. They're optimistic that the plant will deliver its promises. They're now aware of the impact of mining on the environment, but this does not compare to their hopes for economic viability. If the recovery performance of the new technology doesn't equal that of the traditional, they'll reject it unless we explain that the recovery rates are more or less equal. (ComDev Officer, Gigi, KII Transcript lines 1267-1273, page 31).

"Kumbaga i-number one to ten nato naa pa lang ta sa one-two. One to two pa. Kung muabot pud tag five buot pasabot gasugod na ta ug market didto sa mga miners. Kana karon lagi kami maghesitate pa, murag di pa madawat ba sa tawo. Ika-duha, di pa gyud mudawat ang tawo didto pa dapita." (If implementation had 10 steps, we're still at step 1 or 2. If we reach step 5, we would have already been marketing. We're at that point where the people are still hesitant about the technology, some even resistant.) (NIMDC Officer, Dino, KII Transcript lines 696-701, pages 16-17).

While the clamor for copper recovery is valid, the project staff is hesitant to continue with the tests because copper is not among the minerals covered by RA7076 or the People's Small-scale Mining Act of 1991. This will only render the testing efforts futile. One of the key informants said,

"Usa pa jud ana ang restriction sa commodity para ra sa gold, silver ug chromite. So kung naa na tay copper unsa naman?" (The restrictions on gold, silver, and chromite contribute to the hesitation. What will we do with copper once we have it?) (PLGU Officer JJ, KII Transcript lines 253-264, page 7).

This concern has opened the discussion for the issue of lobbying and the problem of small-scale miners in terms of their lobbying power.

"Wa jud lobbying power ang small-scale. Ang large scale naay Chamber of Mines so ang usa ka kompanya adunay 1,000 ka emplyado pila na ka botante so ang Congressman mapugos jud dili pareha sa small-scale nga pila raman intawon unya maayog pareha sa Iglesia nga usa ra katingog ang paminawon pa ingon unya pila sila kabook nga pwede sila mopadaog o mopapildi ug kandidato ana makapugos jud sila, pwede ilisdan na tanan pero ug wala apiki jud kayo. Sige meeting kay naay proposed amendments. Wala basura ra jud gihapon na, wala jud tay lobbying power. Kapila na nagsummit para mopabor, maski open restriction langsa commodity, gold chromite ug silver, so unsaon man ni?" (Small-scale miners have no lobbying power. Large scale mines have the Chamber of Mines with around a thousand voting employees who have the number to influence a Congressman. Small-scale mines don't have this and a strong unified vote like that of the Iglesia ni Cristo that can determine the course of politics. Meetings are rendered futile because proposed amendments do not get approved by government. This has happened so many times before when we wanted to have the restrictions for gold, chromite and silver eased.) (PLGU Officer JJ, KII Transcript lines 257-264, pages 6- 7).

Faced with these challenges, the stakeholders have committed to resolving these issues. Discussions between the PLGU, DOST XI, and other stakeholders continue.

CLINN-GEM Technology and its Transition

Farid (2015) claims that innovation refers not only to the processes that invent new technologies but also to those for further development. These inventions include production, adaptation, and transition, which are purposely designed to suit the needs of end-users so they can retire from another technology. Freeman (1997) relates this process to diffusion, which is the spread of new technology into the wider society. With these premises, technologies must be accessible and well-adapted.

Avelino (2011) says that the purpose of transition is to effect change eventually leading to sustainability. Typically, transitions do this by executing projects to produce outputs where the output is some substantive change in the community. Transitions, therefore, primarily consist of processes and outcomes/substances. This section attempts to

discuss the process of transition and its substance or outcomes.

The Transition Process

The field-testing project is a research and development project. Looking at the technology life cycle, CLINN-GEM is at the research and development stage. However, in terms of the diffusion of technological innovation into society, a breakthrough in mineral processing is observed. Fundamental changes are occurring in existing structures through the interplay of economic, social, and cultural forces.

The transition process for the field-testing project started with the pre-deployment stage. It is a period where CLINN-GEM technology is about to make an impact. The activities during this phase are a) consultation, orientation, and organization of stakeholders, b) public consultation and information dissemination, c) benchmarking activities, d) ocular inspection and surveys, e) signing of the first MOU, f) conducting coordination meetings with stakeholders, coordination, and organization, drafting of management and technical tasks, g) groundbreaking ceremony, h) procurement of equipment, and i) acquisition of permits, clearances, and certificates. These activities focus on community organizing, building social networks, and establishing legal grounds that serve as foundations of innovation. The activities create a platform for the stakeholders to participate in the processes. Also, it allows for collective and democratic decision-making.

The pre-deployment phase is followed by the deployment or take-off phase. Take-off happens when a system shift begins. During this phase, the community's participation in activities has become more significant because they have already participated in research and become recipients of capability pieces of training. Some have also been directly involved in the construction of the mineral processing plant. Activities undertaken highlight community building by mobilizing participation (Midgley, 2014). The importance of developing knowledge, skills, and attitudes is also emphasized as the system shift begins.

The commissioning phase is technical which stakeholders are invited to witness for transparency purposes. The turnover phase is considered the breakthrough phase when fundamental changes begin to occur. During this phase, the organizational structure gets reorganized. It happened when the

mineral processing plant and CLINN-GEM technology are entrusted to PLGU. This reorganization has led to several changes in the roles of the stakeholders. The delegation of assets and powers is indicative of empowerment, allowing the community through the PLGU to expand its capabilities in the mineral extraction process.

The results of the study reveal that the strategies most vital to the transition were those that involved social and human capital, that is, community development and investment in skills and knowledge. These results agree with Jesus, Carvalho, Fernandes, & Bento's (2017) who claim that community engagement is an essential aspect of transition while community involvement activities are requisites to community change (Homan, 2004). Meanwhile, human capital or investment is believed to be an essential element of empowerment. Thus, aside from providing the technology, the project empowers the community by providing its members with technical and livelihood opportunities.

The Transition Substance/Outcome

A transition's purpose is to effect change that leads toward sustainability (Avelino, 2011). Transition results in changes that could be evolutionary or teleological (Rotmans & Loorbach, 2010). The field testing of CLINN-GEM resulted in the organizational, knowledge, economic, environmental, and social changes.

For this study, organizational change refers to the changing roles of the different stakeholders during the different transition phases. Despite the application of a multi-stakeholder approach in the field testing project, the different stakeholders took shifts in leading each project phase. UP Diliman played a significant role during the development of the technology. DOST XI led the stakeholders in the establishment of the mineral processing plant and field testing, while the PLGU and DOST XI were responsible for the operations and sustainability of the mineral processing plant. These changes were based on the function, character, and resources of the different stakeholders. As the community's role in the project progressed during each phase, they also shifted from being simple beneficiaries of the facility to becoming its operators and vanguards. Meanwhile knowledge change refers to the shift in the primary ways of mineral processing. Several changes in knowledge happened in the project. First, manual and expensive mineral extraction processes shifted towards cheaper and more efficient processes. This resulted from digitalization

and mechanization brought about by new machines and equipment. Another change occurred in the techniques used. From the amalgamation and cyanidation of traditional technologies, the new technology brought in gravity concentration and flotation. The third knowledge change is proper waste disposal. The new technology introduced a more efficient wastewater treatment process. A fourth change involves mineral extraction. Hazardous chemicals like mercury and cyanide have been eliminated in observance of health and occupational safety standards.

The knowledge change made several impacts on the stakeholders and the community specifically on the operations group. First, is the realization of the efficiency and cost-effectiveness of CLINN-GEM. Second, is the realization that mining is possible with alternative processes that are safer and friendlier to the environment. Third, is the possibility of a proper waste disposal system as well as the awareness of health and occupational safety hazards posed by mineral processing. On the other hand, the economic change refers to livelihood and infrastructure improvements in the barangay brought about by the field testing project. These changes include road restoration and improvement, installation of a three-phase electrification system, and additional livelihood sources such as employment in the mineral processing plant, food processing, and cosmetology. Road restoration and improvement is an initiative of the local government unit to improve accessibility to the facility. The three-phase electrification system was installed as a requirement of the mineral processing plant operations but its use is limited only for this purpose. Since the community has access to the system, they also benefit from stable electrification. The project also provided the community with additional livelihood opportunities in the form of skills training.

For this study, the environmental change refers to physical changes in the natural surroundings such as the newly planted lumber and fruit-bearing trees. This is a result of the community's increased awareness of green and clean mineral processing techniques, which they learned from the different trainings and activities conducted by the implementing team. The residents have expressed their gratitude for the additional trees in the area which not only help preserve the environment but are also possible future livelihood sources. The new technology has also allowed for the release of clean water (instead of dirty wastewater) to bodies of water after treatment in the plant. The effects of this process, however, remain to be tested.

Lastly, the social change includes the increased visibility of government officials in the community, inclusivity, women's use and access to the mineral processing plant, and compliance with government rules and regulations. These changes are brought about by the number of activities conducted from the pre-deployment up to the turn-over phases. The residents have expressed their appreciation of the government's physical presence in the area for this allows them to more conveniently convey their concerns which the government can help address.

The results show that technological transition leads to various changes. As the technology innovation diffuses (towards adoption), the demographic cycle also does. As innovation takes off, knowledge changes occur. Socio-economic changes surfaced during the innovation breakthrough. This result concurs with Seyfang et al.'s (2010) argument on the role of social movements in technological transitions.

Drivers and Actors of Change

The Scottish Executive Research (2006) proposed several factors which drive change such as norms and habits, key influencers, groups, infrastructure, savings, financial instruments, information, and government intervention. Other important aspects to consider are power and community decision.

The stakeholders implementing the field-testing project have a common aspiration – the vision of achieving a progressive, peaceful, gender-responsive, empowered, and environment-friendly mining community. This vision, along with other factors, drives the stakeholders to initiate, support and accept technological change. It paved the way for the creation of transition agenda and created a platform for them to organize and experiment at different levels.

At the niche level, the UP Diliman, DOST- PCIEERD, and DOST XI were key influencers as they were the ones who introduced the change. As an academic community, UP Diliman is driven by its desire to synthesize and systematize local knowledge on mineral processing methods, and develop and roll out an alternative technology that addresses the economic and environmental risks of hazardous and low-end technologies in mineral processing. Meanwhile, DOST-PCIEERD as one of the three sectoral planning councils of DOST mandated to serve as the central agency in the formulation of policies, plans, and programs in industry, energy, and emerging technology sectors funded both the

development and the field testing of the CLINN-GEM. Meanwhile, regional center-DOST XI was mandated to provide central direction, leadership, and coordination of scientific and technological efforts to implement the field-testing project.

Other academic partners such as the CVSC and University of Southeastern Philippines (USEP) who are mandated to conduct research activities conducted baseline studies such as value chain analysis and environmental impact assessment that were necessary for the field-testing project.

At the meso (regimes) level, the LGUs played crucial roles in the adoption of the CLINN-GEM and in ensuring the sustainability of the mineral processing plant. Government officials from the barangay to the provincial levels supported field testing from the onset of the project up to the present. The LGU's support and commitment sprung from their interests and investments in the project. CLINN-GEM and the field-testing project will not only address the economic and environmental problems of small-scale miners in the province but it offers the community and the entire province economic and investment opportunities in terms of revenue, livelihood, infrastructure, and tourism. Thus, the LGU poured out human and financial resources to ensure a successful outcome. These interests and commitments were recognized not only by the project staff and the small-scale miners but also by the residents of the community. Aside from commitment, government officials also exhibit power and authority over their constituents. Subordinates obey and follow directives while residents and community members take cues from their officials. These results support the importance of change agents in exercising power, influencing others' behavior, and directing the general course of events. The results also prove that it takes several forces operating together to realize change. Avelino (2011) mentions government intervention as a vital change driver.

At the macro (landscape) level and considering the plans and directions, NIMDC, CSOs, and the policy-makers will play invaluable roles in promoting and introducing policy reforms. NIMDC as an industry partner representing the small-scale miners are attracted to support the field-testing project because they will directly benefit from it. They provided ore for the tastings and helped in linking the project staff and researchers to their members. But with the current status of the mineral processing plant, they are faced with the challenge of convincing and influencing other members and miners to

adopt CLINN-GEM. Thus, they continue to support optimization efforts so they can easily market and lobby the technology. Although CSOs were not initially considered partners in the implementation of the field-testing project, the intention to include them in future endeavors implies the recognition of their potential in effecting change as advanced by Seyfang, Haxeltine, Hargreaves, & Longhurst (2010).

The fulfillment of an empowerment and sustainability vision, agency mandates, interests, and investments are essential drivers to change. These drivers motivate the different change actors to initiate, support and adopt change. The presence of the different actors driving the transition process at different levels following key elements of transition management identified by Kemp, Parto & Gibson (2005): a) development of sustainability visions and setting transition goals; b) use of transition agenda; c) establishment, organization, and development of transition arena for actors, use of transition-experiments and programs for system innovation; d) monitoring and evaluation of transition process; e) creating and maintaining public support; f) portfolio management; g) use of learning goals for policy and reliance on circles of learning and adaptation

Further, the results prove the advantage of a multistakeholder approach in rolling out the technology for the people and advancing technological transition. Aside from providing mutual support, being vocal and receptive to each other ease the transition process. At present, the strategy of strengthening the organizational structure by combining the human and financial resources of DOST XI and PLGU is an essential approach to

address the current challenge of CLINN-GEM which is the optimization of the technology. However, this effort will be put to waste if their problem with the intellectual property rights limitations and the lack of UP counterparts persists. The local counterparts admit that they need UP Diliman to assist them optimize the technology.

Another concern observed about actors of change is the role of the community as an agent of change. While the community is directly benefitting from the project, fears and doubts hinder the people who are directly involved in the field testing to promote the technology. And while community engagement in all field-testing phases was observed, their full acceptance of the project is uncertain unless gold recovery issues are addressed. These circumstances disable them from becoming active actors in charge during the transition process.

Social Development Perspectives in CLINN-GEM Technology Transition

The transition of the people towards getting back their wisdom which was articulated by the academic community is a social development journey. Documenting this journey contributes to enriching and understanding social development perspectives and building theoretical constructs for social development practice.

The study explored the complex system of technological transition phenomenon using social development lens and documented the experiences of a community undergoing technological transition. The learning experiences and results suggest this conceptual framework (see figure 3).

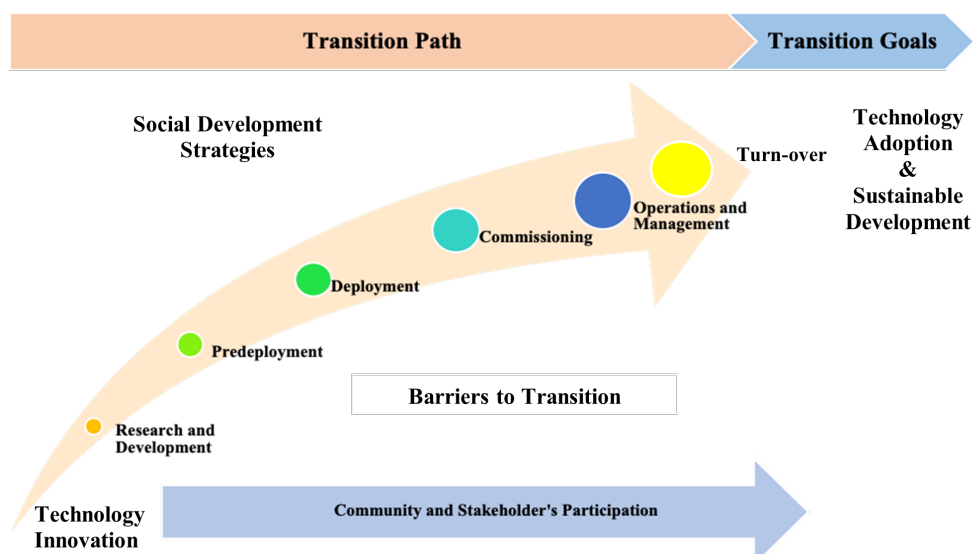


Figure 5. Idealized Technology Transition Process towards Sustainable Development

Figure 3 shows the transition path or the process by which the transition was made and the factors which contributed to the issues encountered in the process. Also, it shows the transition goals which need to be achieved by the stakeholders and the community. The figure further depicts the importance of social development strategies, community, and stakeholder participation in all the transition phases.

Phase 1 (Research and Development)

The development of technological innovations is the first crucial step to sustainable development. But without the resources, the people who are occupied with subsistence cannot initiate technological innovations. Thus, technical and social development scientists play a crucial role during this phase. They must articulate innovations and interventions for the people. But, while the development of technological innovations is likely technical that would require specific consideration i.e. technical laboratories and experts which are not available in communities, integration of the social dimensions, aspects, processes, and strategies are necessary. Thus, technology developers must consider local knowledge and context.

Consideration of local knowledge and experience as sources of information during research and development is vital. People with years of experience in the operations of the industry have equipped themselves with knowledge, especially on practicality. They can provide insights into things that work and do not work in the field i.e. suitability of the principles of the technology to the capabilities of its users such as the use of machines, and health and safety equipment.

Another aspect that is vital in this phase is the consideration of the needs of the technology's end users or the importance of productivity. The people are accustomed to the idea that the technology and projects introduced to them could provide for their needs. Thus, without assurance that the new technology is better than the traditional and no proof of economic gain, the community's participation in the operations will not be sustained.

Phase 2 (Field Testing)

The field-testing is the first step in rolling out the technology. This may be the most

difficult phase during the transition because it combines all aspects related to the use and adoption of the technology. It is also during this phase that the people and the community directly participate in the activities. To hasten and ensure a successful transition, stakeholders and implementers of technology innovations must consider the following in each transition phase.

Pre-deployment. Social preparation must be considered the most important aspect of this phase while technical preparation is only secondary. The primary goal of social preparation is to win the community's trust for the adoption of the new technology. Without social preparation, issues may later arise which could affect operations, production, and eventually adoption. To do this, community organizing, community building, and community development strategies must be considered. Consultations with the community may be made but these should not be one-sided. Although it is necessary to make members of the community understand the ill effects of traditional technology on the environment, it is also equally important to listen to what the community has to say on the issue. Community leaders are especially indispensable at this phase for they know their people best and know too how best to deal with them.

Deployment. Timeliness of construction and people's participation are major considerations during this phase. During this phase, the technological transition is taking shape as the construction of infrastructure begins. The project implementers must secure procurement mechanisms to avoid delay and ensure the timely conduct of activities. Also, community organizing and involvement must be intensified, inclusive of capability-building programs and employment strategies because, in this phase, members of the community are directly involved with preparations and operations. This involvement is crucial since this is the time when people acknowledge the economic opportunities that come with the deployment of new technology.

Commissioning. The efficiency of machines and readiness of the operators are primary considerations at this phase because it is here that operators get to test the technology for the first time. The technology must ensure

its functionality by complying with operational parameters because rumors are expected to emerge at this phase. Operators are to talk about their experience in the operations with other members of the community and a technology with glitches may spark negative talks. Community development officers must know how to handle the spread of information at this point.

This phase also tests the investments in the skills, knowledge, and readiness of the operators. The success or failure of the technical training and preparations is revealed here and the functionality of the technology partly relies on the way it is operated. Also, the capacities of local counterparts must be strengthened so that they do not have to rely all the time on their counterparts to troubleshoot problems. This also prepares them for the future when the technology is completely entrusted to them. This only goes to show that training has to be done with the goal of autonomous functionality.

Operations and Management. This phase has yet to happen, but based on the preparations, it was observed that compliance with government regulations will be the primary contribution of CLINN-GEM to ease the informality of small-scale mining, which has made it prone to criticism. This is important because, for the first time in Philippine mining history, a serious attempt is made to formalize the complexion of small-scale mining by giving it the legitimacy that only large-scale mining enjoys.

Important considerations for this phase include the efficiency of the technology, the safety of operators and employees, and the promotion of inclusive and gender-sensitive mineral processing operations. As promised, the technology must be cheaper in terms of operation and environmental costs; it must be efficient with a shorter processing time and most importantly, must yield higher gold and other minerals recovery. Thus, continuous research must be conducted. On the other hand, the safety of the operators and employees should be a top priority during operations. Also, the mineral processing plant's operations must promote inclusivity by allowing all sectors to avail of its services and benefits. Lastly, its practices must be gender-sensitive. Operators shall promote equality

and avoid or eliminate gender stereotyping, abuse, and violence. To do this, continued capacity building must be implemented.

Turn-over. The autonomy of the end-users to use and innovate the technology is a foremost consideration. Ideally, technology innovations are turned over once proven operational and have been optimized; unfortunately, this has not happened in this case. The turnover of the mineral processing plant, its management, and underlying responsibilities were made before its operation. The main problems of the receiving party are the restrictions and limitations of their operations because of the IPR and other limitations in the MOA. This difficulty still has to be addressed in the transition.

Aside from end-user autonomy, this phase is confronted with sustainability concerns. Thus, continuing community organizing and development efforts, promotions of the technology, and policy advocacy are necessary. The build-up of promotional activities such as the development of information, education, and communication (IEC) materials, campaigns, and other community activities must be intensified while continuing policy advocacy with other stakeholders must be strengthened.

Meanwhile, since social development is a journey toward a better life; it is both a process and an outcome. From the people's point of view and based on the learning experiences with the CLINN-GEM, several things can be deduced.

First, technological transition process as Social Development process. The journey of people towards getting an environment-friendly and sustainable technology highlights the following aspects: The transition is a process focused on transformative change. Transition is dynamic. It is a long-term process, and completing a system change takes time. The transition phases of the CLINN-GEM included the development of the technology and field testing (pre-deployment, take-off, breakthrough, and stabilization). Movement between phases included changes in the organizational structure, roles, and responsibilities of the stakeholders and the community. These changes enable the stakeholders and the

community to commit and initiate change to address existing problems. Also, the transition is a progressive process. Transition is non-linear; the rate of change varies over time but continuously moves forward. CLINN-GEM as a technological innovation goes through a continuous research process. Thus, its research and other activities during the transition phases halt, hasten, or delay the transition process, but it always brings about changes in the community. Most of these changes are steady improvements in the social conditions of the community. Moreover, the goal of the transition is the people's well-being. A clear vision is crucial to a successful transition. Efforts in the development, field testing, and planning for adoption phases must have a guiding principle. In the case of the CLINN-GEM, the vision is anchored on the desire to give back to the people their wisdom for them to achieve a good life. The stakeholders' commitment to achieving this is what drives them to address problems, issues, and challenges and urges them to succeed. Furthermore transition is a multidimensional and multifaceted process. Developing and introducing technological innovation involves the interplay of technical, economic, social, political, environmental, and gender dimensions. CLINN-GEM did not only change the knowledge realms of mineral processing but it transforms attitudes, practices, and socio-economic conditions. Thus, the transition is multidimensional in the sense that it affects all aspects of community life. The transition process is interventionist. For change to occur, deliberate efforts must be made toward social improvement. These may come in the form of projects, programs, and policies. Actors are also needed to make change happen and they may come in the form of government agencies, policymakers, organizations, and the community. For CLINN-GEM, the people are the inspiration for change while the academic community, government agencies and units, and industry sector made it happen. A multi-actors or stakeholder approach is vital to speed up the transition because each is expected to possess certain resources or capabilities that can be mobilized during the process.

Second, the transition outcomes as Social Development outcomes generate impacts. Interventions, such as technology, function as an investment. As an investment, the CLINN-

GEM technology is expected to contribute to achieving a good life and its returns go to individual households and communities. New knowledge, skills, and products hold potential solutions to economic, social, and environmental problems. The impacts of the technology are not yet very evident for now because they entail a longer period to surface. However, technological transition outcomes are heavily dependent on the following factors: clear vision and goals; firm commitment and available resources of actors; efficient technology for sustainable operations; and, policy formulation and enforcement. In CLINN-GEM, the vision and goals served as a framework for setting parameters during its development and as a measure of technical efficiency. It also served as means to direct actions and future decisions. Meanwhile, the commitment and resources of key actors determine the strength with which changes are carried out in the community. Moreover, the efficiency of the technology to achieve positive results shapes its technological outcomes. Lastly, policy formulation and enforcement are essential factors in the speed and extent of its outcomes.

Conclusions

The CLINN-GEM technology is a synthesis and systematized articulation of local knowledge on mineral processing which aims to address the adverse impacts of mineral processing using traditional hazardous and low-end technologies in small-scale mining. The developers of the technology roll it back to the people for them to use to maximize their resources to attain good life leading towards sustainability.

The CLINN-GEM transition process follows a technology innovation cycle that starts with documenting what the people know about mineral processing and establishing methods to systematize the process (research and development) towards rolling it back to the people (adoption). During the transition, restructuring of organizations, physical, cognitive, and social systems was made to effect change in knowledge realms and the social conditions of the community. The transition process was not an easy one. It was fraught with issues and faced several issues such as acceptability, project delays, information and communication gaps, and limited resources. Some of these issues have been resolved through proper communication and community engagement, but the others remain to

be fully addressed. Meanwhile, technical, political, social, economic, and environmental risks need to be addressed to ensure a successful transition.

Recommendations

The results of this study provided theoretical constructs of social development in technological transition based on the experiences in CLINN-GEM. Moreover, to help address the issues and challenges of the CLINN-GEM technology and ensure its sustainability, the stakeholders shall continue to provide human and financial support for the project's research and development. The operations of the mineral processing plant must ensure its viability and the environment's sustainability. Moreover, the stakeholders and the community should strengthen partnerships to encourage the utmost adoption of the technology through community development activities, capability building, and community mobilization. They must consider seeking assistance from development communication professionals in translating technical jargon to laypersons' language. Lastly, the social development strategies during the transition process need to be re-examined and the applicability of other strategies must be explored. The strategies may include technical training and human capital training through microfinance and financial assistance to support small-scale miners and mining cooperatives.

While the study explored several variables regarding technological innovation and transition, its scope and complexity necessitate further study. It is recommended that further research be undertaken focusing on the people's involvement in all phases of technological transition. Future studies on technology innovation may consider the bottom-up method or participatory approach to research and development. Other studies shall focus on the challenges of a transition process in an extended period. Time was a significant limitation of this study; continuous monitoring and evaluation of the transition process could help identify challenges during operations and turn-over phases that this study was not able to observe because of limited time. This study could direct future decisions to address the challenges and ensure a successful transition. Also, re-examination of the transition outcomes and impacts assessment is vital. Time is an essential element of transition studies. The study employs qualitative research methods, but once the technology is optimized and adopted, transition outcomes can be re-examined using both qualitative and quantitative indicators. Given the importance of the element of time in transition, an

impact assessment or a longitudinal study can be done after some time (a decade perhaps) to trace the subsequent changes and impact of the CLINN-GEM. This study has already provided initial data that can be used for future studies on the long-term impacts of the technological transition. Finally, a re-examination of social development strategies and context as a crucial element in transition studies. Since CLINN-GEM is implemented in four regions in the country, the same study can be conducted in each site, or a multiple case study can be conducted to find out similarities and differences in their transition processes, strategies, and outcomes.

The development of CLINN-GEM is a concrete manifestation of the government's efforts to address the mineral processing concerns of small-scale miners. Through the experience with CLINN-GEM, thus a national policy to support the replication of the mineral processing plant in other small-scale mining communities to increase the accessibility of the technology and a strict compliance, monitoring, and enforcement of environmental laws are necessary to hasten the retirement of traditional technologies and the adoption of the CLINN-GEM shall be considered.

Declaration of Conflict of Interest

The author declares that she has no conflict of interest.

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