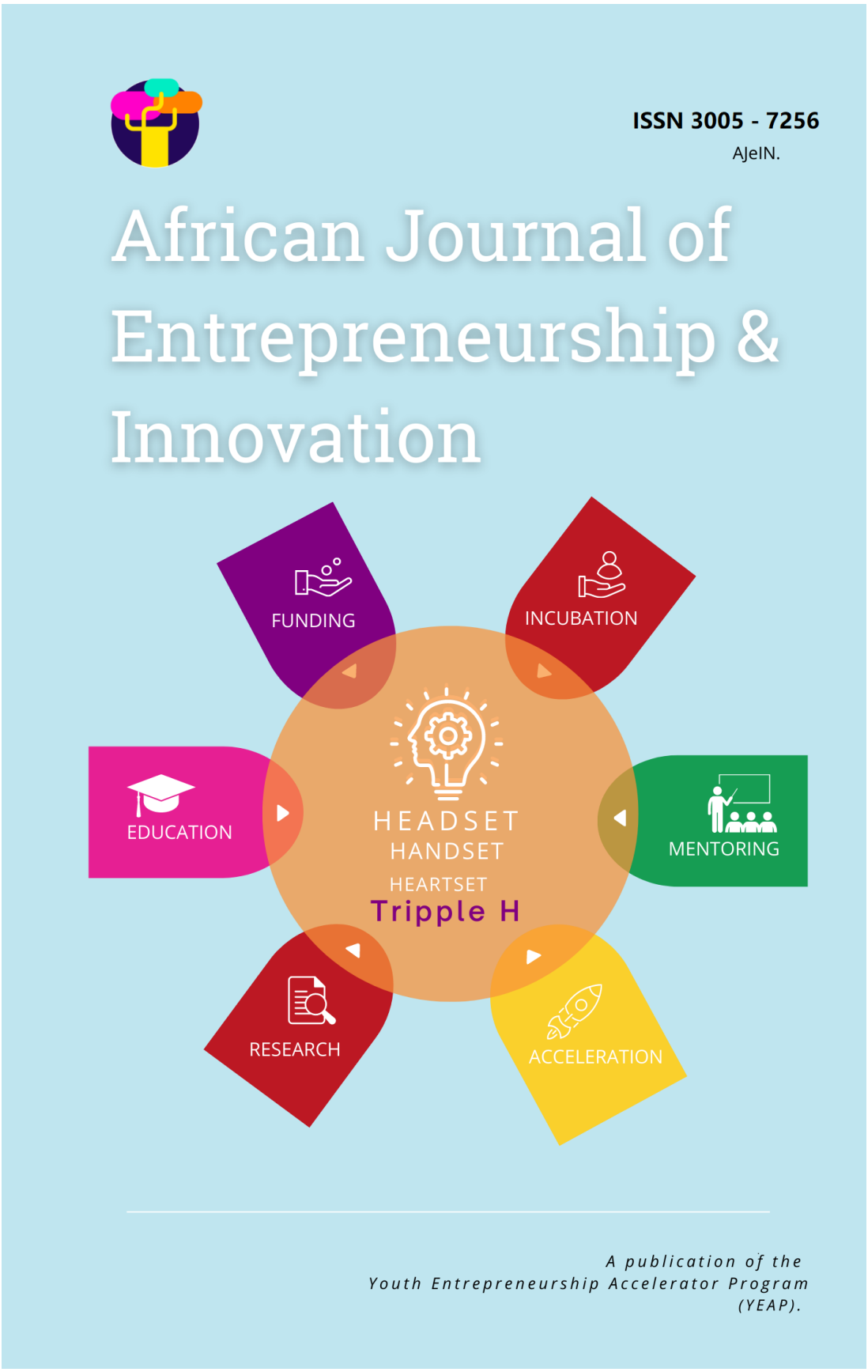
https://uonjournals.uonbi.ac.ke/ojs/index.php/ajein
ISSN 3005-7256



AJEIN https://uonjournals.uonbi.ac.ke/ojs/index.php/ajein
December Vol 2 No.1, 2023 PP 1-17 ISSN 3005-7256

African Informal Sector Inventors: Inventing Outside their Disciplies

By: Wangai Njoroge Mambo[1]

Abstract:
The study uses Nderitu a Kenyan airplane inventor who attempted to invent an airplane as an example of a typical Informal sector inventors, who invent in high scarcity environments, with limited or no invention theory and outside their disciplines. Finding out how informal inventors invent is important because it can help improve the way they invent which can help a developing country as it would improve technology innovation that would lead to more commercialization of inventions and economic growth. The paper surveys how Nderitu went about inventing, how interacting organizations reacted and how this can be related to invention theory. Informal sector technology inventors are part of global maker movement. This study argues for linking of informal sector maker inventors with invention and innovation theories. A literature review of Nderitu inventing process and information available about how organizations responsible for supporting invention in innovation ecosystem reacted was carried out.

Key Words: *design thinking, informal sector, invention theory, maker movement*

Introduction

The study examined what has been published about Nderitu's a Kenyan informal sector inventor who represents a typical African inventor to find how inventor went about inventing the plane and extrapolated lessons learned and invention concepts to create picture what happened. The inventor was an IT graduate who invented a plane by adapting a car engine. Invention captured the attention of the nation and media for a week. When time came to test the plane the aviation authority failed to authorize it. The conversation about invention died as fast as it had appeared in media and public. The records remain in media houses as archives that are difficult for public to access given people don't record TV, radio broadcasts and those who buy physical newspapers don't keep them for long. The easily accessible records are on web, they are brief and few. It's an old African traditional informal invention story, since time immemorial inventions are created based on trial and error are rarely recorded, studied or explicitly linked to existing invention knowledge. Most informal and formal inventions quickly come to public limelight and disappear as quickly as they appeared.

Typical informal sector inventors who create inventions amaze the public and quickly get large media and society attention which dies as fast as it came to existence. Public invention amazement phenomena should be used to diffuse invention and innovation knowledge to the masses. Mass

[1] *Adjunct Lecturer, Computing Department of United States International University, Kenya, Email: mambown@protonmail.com*

innovation can be supported by transdisciplinary design tools (Tate, 2010). Such tools should be made easier to adopt where they exist or created where they don't exist. For example basic creativity, innovation, invention and entrepreneurship courses for general public should be provided for free online using artificial intelligence enabled massive open online courses.

The study classified informal inventors into four categories: those who invent using indigenous knowledge, those who use predominantly global knowledge but invent informally inside their disciplines, those who combine both indigenous and global knowledge in nearly equal proportions and those who invent outside their disciplines knowledge. Informality comes from not basing their inventions on invention theory, nature of their business, business models and their operating as individuals outside institutional systems. Informal sector inventors who invent outside their discipline belong to the maker movement. Studying informal invention and innovation aspects presents opportunities and challenges. Their inventions are based on trial and error and tacit knowledge rather applied research and development which leaves very little trace of documented activities. Informal maker movement inventors are transdisciplinary since they invent beyond their disciplines (Nicolescu, 2010). For example Nderitu acquired his knowledge from aeronautics; assimilating involved transforming knowledge into a form inventor could comprehend. Inventor never registered a firm but the way inventor went about inventing was informal and a kind of temporary business as the invention was carried out as a project and a group of people was contracted and inventor informally managed them. Informal inventors like Nderitu have many similarities with single informal sector startup owners because one difference is they carry out invention projects with no goal of commercializing them, Single owner technology startups are transdisciplinary since the owner performs all relevant functions including technology innovation, startup creation and management that is best done using unified from these areas, domains and disciplines (Mambo, 2022). Single informal sector inventors have to cross these bounded regions in addition to crossing formal and informal boundaries.

The study's research questions are:

(a) How do informal sector inventors invent outside their disciplines based on literature review of Nderitu's plane invention?

(b) What information is available on how formal organizations that interact or are supposed to support inventors react to Nderitu the inventor?

(c) What connections can be made between informal inventing activities with invention practices

and theory?

The remaining part of study is organized into methodology, nature invention, invention learning, support organizations, artificial intelligence for innovation, recommendations and conclusion.

Research Methodology

The study used appreciative inquiry (API) (Bushe, 2012) and literature review, analysis and synthesis research methods. API is based on identifying what works so that it can be used to create what could be. AP consists: discovering by finding and appreciating what works, dreaming by envisioning what could be, co-designing by constructing what can be done to implement dreams, destiny paving way for what will be (Kurz, 2012), instead of wild dreaming, dreaming springs from what works and drives design to create destiny. Using symbol substitution techniques on a Japanese proverb it becomes: dreaming without action is waste of time; action without dreaming cannot achieve much. Symbol substation is basis of intelligent thinking that can be used as a transdisciplinary research and development technique by substituting proverb symbols (Mambo, 2021).

Knowledge required in API to pave way for what will be comes from interactions of discovery and dreaming, dreaming and designing, designing and destiny (Kurz, 2012). API emphasis imagination and exploration and is therefore suitable for problems requiring these type of task. A common saying is imagination is more important than knowledge, while both of them are important but where knowledge is limited then imagination which is unlimited can be main driver of progress. Ideally combining enough knowledge and imagination produces best results.

Google search engine was used to search for available publications. The search string used consisted of Nderitu, innovation, innovator invention, inventor, informal sector. No journal or published books were found concerning Nderitu's invention so grey literature was used. Research articles found about inventors in similar contexts were used to link Nderitu's invention activities with invention theory.

Results and Findings

This section presents results of literature review ideas found were extended and connected with each other and with invention literature.

Inventor's Motivation, Process and Invention

The author found no journal article or book dealing with Nderitu's attempt or any other publication which could provide theoretical basis that future inventors and innovators could use to increase chances of success. Such publications are useful foundation for other informal inventors or those who want to join their movement as it would inspire them and could invent more intelligently based on experience of those who tried to invent before them. According to innovation capability building model innovation attempts out of ordinary are dismissed, because organizations lack basic understanding of importance of innovation (Essmann and Perez, 2009). It seems informal inventors are not funded, are ignored by some researchers, innovation researchers are few and overwhelmed by to much urgent and important research resulting in lack of capacity to do all that research. The inventor like other Kenyan informal inventors and innovators ended in disappointing failure, no lessons were learned by other informal sector, society or government. Africa has no systematic ways of sharing, analyzing and evaluating innovation and invention success and failure stories which hinders technology capability building (Khalil-Timamy, 2002). While this has improved since this research was done it has not reached the tipping point to make significant contributions. According to the Nderitu when one says one building a plane it seems one is an alien from the moon (Smith, 2010). Aliens are people who can't be trusted and could possibly be designing their ideas and systems to mislead us. If significant proportion of population views inventors as aliens or according to saying any advanced technology is not distinguishable from magic these perspectives would discourage potential inventors. Nderitu is typical example of Kenyan informal inventors who stories can only be found on the Internet's webservers like You Tube. Mainstream printed media though they published the inventor attempts cannot be easily located and those that are available are few and present a shallow outline of whatever happened. Possibly physical newspapers should create searchable databases where it would be easier to purchase important articles similar to way most online journals operate by providing online articles for purchase.

Nderitu's motivation to build a plane was to motivate local research and innovation (Robinson, 2015) a noble goal. The inventor's created around 18 airplane versions increasing reducing their weight from 500, 180 and 140 kilograms respectively (Karanja, S. 2020) indicating improvement through learning from doing and from online sources. The inventor failed carrier dream was becoming an aeronautical engineer and was his inspiration to invent a plane (Citizen TV, 2010), a dream that started in childhood (Smith, 2010). If many people desired to promote local research and innovation, their efforts can be

enhanced by forming invention and innovation societies that help share and combine their efforts, knowledge and experience. Childhood creativity, invention and innovation dreams can be nurtured by providing interesting science and design fiction books and cartoons designed to nurture creativity. Childhood dreams are one of longest lived and strongest drivers of adult activities.

Nderitu's invention belongs to informal out of discipline of invention. The inventor's training was in Information technology and was inventing in aeronautics. Inventor hired skilled artisans working in workshops, and inventor provided guidelines on how invention components would be built and assembled. He used aeronautics knowledge from Wikipedia, but since he had no training in aeronautics assimilation process of acquiring knowledge and building skills was far from ideal. Inventor's invention is a maker movement invention but unlike mainstream movement in developed countries tools, process and workshops were improvised and far from ideal for invention. Most patented inventions are created by inventors who cross different technology domains during their careers (Alstott, Triulzi, Yan and Luo, 2017) although Nderitu's tried to cross for information technology to aeronautical technology by learning from doing and published sources on his own rather than by working in aeronautical environment. His process acquiring knowledge and building capabilities was very slow process compared process of working in organization that manufactures planes. For large inventions like an airplane invention from scratch was bound to fail because tasks were beyond individual capability, invention duration was less than time required to build necessary skills and knowledge were from outside inventor's discipline. The only way invention could have had slightest possibility of success is if invention was built by reusing old parts of planes. Planes parts cannot be built in small general purpose Jua kali workshops with materials not designed to make planes. Information technology is a distant discipline from aeronautics making it difficult for IT professionals to learn about plane aeronautics, electronics and mechanics on their own. It may be easier for aeronautical engineers to learn about IT since they learn several computing courses while IT professional are unlikely to learn any mechanic or aeronautics course. The inventor's invention was based act of insight from trial and error cumulative learning that cumulatively adapts and combines exiting basic inventions until an invention created (Usher, 1929). This indicates existing theory fragments and basic inventions can be synthesized by informal inventors. Learning from past inventors also helps. For example Tesla who worked with Edison created a popular widely used saying that a little theory could have helped Edison save 90% of his efforts. Einstein said he failed 99 times before succeeding the hundredth time indicating great inventors and scientist fail many times in making grand

inventions and theories. Any inventor's inventing without guidance of theory is less efficient and effective. Nderitu's invention prototype was built by combining basic inventions had fatal flaws and limitations that if not resolved guaranteed the plane would never fly beyond a few inches. Nderitu always build working systems instead of starting with cheap throw away prototypes like toy planes or kites.

Informal sector inventors can reduce their costs; accelerate learning and capability building by developing small incomplete learning invention prototypes. Informal sector innovators prototype their innovations which can be better prototyped by linking them to formal sector innovation for scaling in universities (Manyati and Mutsau, 2020). This process can be applied to informal sector invention but exclude scaling up and commercialization.

Invention Learning

Lessons learned by Nderitu were never captured, systematized and widely distributed an indication of country's knowledge management systems weakness. What is captured in literature is shallow explaining what and how inventor went about inventing, improving by modifying and sometimes discarding invention and starting afresh, but reasons and lessons learnt were not recorded. No commentary was found about inventors approach compared to neither other formal or informal inventors nor how invention theory could have helped. The nation also never learned from the inventor's, universities and responsible organizations either never learnt from his failure or if they didn't they never made knowledge available to public. Institutions that could have helped never tried to provide advice that could also be helpful to other informal inventors and would be future potential inventors. From time immemorial until wide adoption of writing African society inventions lessons learnt and invention process were never written and widely distributed. By failing to learn from informal innovations a society cannot efficiently and effectively build its informal sector invention capabilities. Several newspapers reported inventor's invention activities that would interest general public, but didn't link it to invention or entrepreneurship theory or include parts that could aid potential inventors. With similar situations recurring in the continent, it's not possible for now to write history of informal inventors and inventions. History of technology is important in national invention learning. Failure to learn from past invention failures or not recording is a major obstacle technological growth as inventors keep reinventing the same thing and repeating same mistakes wasting resources that could have been used for other useful invention activities. Eliminating waste is

one key Kaizen innovation rule. One principle Kaikaku Japanese radical innovation method system is blame failure on knowledge or approaches not the inventor or institutions (Yamamoto, 2010). This ensures that inventor and support institutions are not discouraged. The inventor's case indicates Kenya's forming national innovation system is not yet effective in assisting inventors

Informal Sector Related Institutions and Movements

The Plane invention was made of Toyota corolla engine, and instructions downloaded from Wikipedia (Rice, 2010) Kenya aviation authority stopped Nderitu's who had invested 5 million from further developing the aircraft and it was right thing do (Rice, 2010). While this was right thing to do, they should have supported and guided inventor to direct invention efforts by directing and recommending right source of knowledge and institutions that would help.

Maker movement in United States of America, Finland lacks theoretical foundation and focus on doing, but research on developing theories is just beginning (Dufva, 2017). While in developed countries make movement lacks theories it has theory fragments that can be used as basis of developing theories. African informal maker movement has no fragments of theory and is based largely on trial and error. Borrowing principles, concepts, techniques and methods is low cost way to start systematizing informal sector and making it more knowledge based (Mambo, 2023). An informal sector industrial revolution can be started through frugal innovation and creating a resilient, sustainable entrepreneurship ecosystem (Igwe and Ochinanwata, 2021). Frugal innovation is method inspired by Indian informal innovation movement that similar to Jua kali informal innovation sector. The maker movement in developed world is seen as possible new form of industrial revolution, a remedy, a cultural movement as well as a pedagogical method the three views overlapping and contradicting each other (Dufva, 2017). From these it can be seen that both developed countries maker movement and African informal technology developing sector are seen as promising ways of starting informal sector industrial innovation revolution. In developing world maker movement is a remedy to building innovation capabilities, innovation culture and can be used to teach technology and engineering to the masses. The Indian Jugaad maker movement and African Jua Kali informal sector are based on Jua Kali as design and design as Jua Kali (Beniwal, 2016). Design thinking is embedded in human culture and is a good starting point for systematizing informal sector design (Mambo, 2023). Design science and design thinking methods could be down scaled and adapted for this purpose. Formal sector frugal innovation was created by analogy inspired design and learning from informal

sector innovation. Design thinking was adapted for frugal emerging markets innovation (Schleinkofer et al. 2019). Since both Jugaad and frugal innovation have many similarities and share a large amount of knowledge, frugal design thinking method is a promising candidate for down scaling to make it appropriate for informal sector. The more systematized informal maker movement is making inroads into Africa, there were five maker movement gathering in Africa and maker movement can drive poverty driven innovation based on necessity is mother of invention (Kraemer-Mbula and Armstrong, 2017). Poverty or scarcity driven innovation is well suited for African informal sector innovation because of lack of funding and resource constraints.

Most government organizations throughout world are not well prepared to support informal sector inventions because they are designed to deal with global knowledge rather indigenous (local) knowledge. Other reasons for institutions in some regions like Africa are lack of innovation culture and their adolescent national innovation system (NIS). East Africa has a nascent NIS's consisting of loosely connected NIS fragments that can be grown to a well-functioning system (Cunningham, et al. 2014) while at same time building an innovation culture. The national innovation system is forming, existing innovation institutions and ecosystems maturing but informal sector inventors are either ignored or these systems lack the necessary resources to support them.

African technology capability building is constrained by or undermined by failure to exploit public domain technologies that are freely available to public. (Khalil-Timamy, 2002). The continent is marginally involved in open source software revolution which is important for its industrialization (Oreku and Mtenzi, 2013). The newer open hardware movement that is more expensive to join is almost unknown in the continent. Few people in African are knowledgeable about patented inventions that could be useful in their businesses. Failure to leverage these sources stifles a country technology building efforts. It's difficult to industrialize but simple solutions like basic understanding of country inventions, innovation theory and state of its innovation systems is step toward building a national innovation culture that can increase a country's invention rate. Most Sub Saharan countries have recently established or are establishing innovation institutions. Many African inventions are not linked with innovation and invention theory and lessons and learnt are not systematized and widely communicated. Problems of high youth unemployment and low informal sector productivity can only be solved by creativity, invention and innovation (Osborn, 1957), without which problems will continue getting worse with population growth.

Support institutions can find low cost means of supporting informal inventors. For example universities could create small student multidisciplinary teams of students from different disciplines relevant to an informal sector invention. In case of Nderitu the team would have one student from each of aeronautics, electronics, mechanics, mechatronics, innovation and entrepreneurship especially those with knowledge on startups or specializing in startups. Including a computing student with entrepreneurship knowledge could introduce computing dimensions like inventor pivoting to inventing aeronautics software. The project would explore how informal inventor could invent better. Such a team could have reduced the invention cost by reducing the number of trial and error trials and enabling inventor budget to be able to do more with less money. The project would record the inventor's activities from knowledge based perspectives that would be made knowledge about invention process available to university community and society for further research and application. The students could present their project progress reports to university community and get guidance on what to add and how to continue the exploration. Since the project goal is exploring not creating the invention it would be cheap for a university to support. As an exploratory project may not come up will a solution but suggestions for further exploration but their participation would have helped informal inventor. However the informal inventor must consent to team getting involved. Nderitu is likely to have accepted such a team since his goal was to promote local innovation and research. The students need to be informed of how to work with informal inventor and be aware that their goal is explore and not to take over the project. The students should be assistants and respect inventor's approaches no matter how ridiculous they may appear to the students. The project students are not experts in informal sector invention and ideas that may seem good to them are likely to more applicable to formal sector and large organizations than in informal sector technology invention. .

Relating Inventor's Experience with Invention Approaches

The research process consisted of studying a typical invention case of informal sector inventors many of whose projects ends in failure. The case was used to reason with ideas from related invention literature to find out how their informal invention process can be improved.

Researchers are encouraged to survey more grassroots innovations in order to derive general ecosystem innovation theory (Sharma and Kumar, 2019). The proposal was from research on Indian grassroots ecosystem research and presented Jugaad commercialized innovations from informal

innovators. Creativity and discovery may lead to invention which becomes innovation if commercialized. Informal invention theory is a first step towards building an informal innovation theory.

Frugal innovation is a global approach based on Jugaad Indian grassroots innovation movement (Brem and Wolfram, 2014). Jugaad is Jua Kali with differences of cultural context. It could be possible to derive a variant of design thinking based on Jua Kali. Design thinking is embedded in human thinking and is good starting point for systemizing informal sector design (Mambo, 2023). Deriving design thinking method based on prototypical design thinking elements existing in African culture can provide a low cost way of developing products that are likely to be easily adopted due to their familiarity to potential adopters.

Frugal is for formal sector what Jugaad is for informal sector both enable innovating for resource scarce environments, frugal approach was created by analogy inspired design of Jugaad (Schleinkofer et al. 2019). By using analogy of how frugal approach was created by inspiration from Jugaad and by taking into account innovators environment it would be possible to create variant of frugal approach for informal sector inventors inventing outside their disciplines. To adapt design thinking to frugal innovation in emerging markets, strengths, weakness, opportunities and threats of applying design thinking to emerging markets were determined and used to adapt design thinking to emerging context. Design thinking extreme programing (DTXP) software development method was adapted to African countries local context by integrating local knowledge (Mambo, 2017). Examining inside, between beyond and across Jugaad, Frugal, adapting design thinking to emerging markets innovation context and design thinking for african country context to increase adoptability presents opportunities for adapting design thinking to informal sector inventors inventing outside their disciplines. Design thinking and learning methods cocktails can be used for capability building in Africa (Nyemba et al. 2020). The cocktail was proposed for formal sector but can be downscaled and adapted for informal sector capability building. Innovation in developing countries is likely to succeed if done in small scale with developing countries as active participants in innovation process (Heeks, 2008). Small scale enables learning before scaling up, lowering cost of failure, making it easier for developing smaller which enable stretching innovation budget.

The maker movement is a grassroots innovation movement that could be used to support informal

inventors who use global knowledge to invent outside their disciplines. The more systematized maker movement is best established in United States of America. Foreign maker movements are diffusing to Africa for example Indian honey bee grassroots innovation movement through African organizations going to learn why grassroots innovation movement has succeed in India and returning to implement lessons learnt in their countries (Gupta, 2006). Learning from other maker movements by informal sector which may be cheaper and easier to learn from than formal sector because they are similar, use similar approaches, they are tacit knowledge driven and deal with resource scarce environments (Mambo, 2023). Analogy is most widely used invention method (Nakamura, 2003) across disciplines and sectors but it has not been used systematically in informal sector. Most analogical methods are similar across disciplines their differences are in problem and solution knowledge used to invent.

Artificial Intelligence Support for Innovation

Artificial intelligence is moving from current technology driven innovation paradigm to one of collaboration between AI and humans. Collaboration between humans and AI systems will improve several types of innovations including grassroots movement (Botha, 2019). Human computational systems based on human and AI systems are already in the market but are not become widely adopted. Innovation capabilities are comparably low for countries in the continent compared to those of developed countries, yet the ongoing artificial intelligence innovation revolution that is driving fourth industrial revolution to improve social technical systems is not treated with proportionate urgency and importance it deserves in the continent. The artificial intelligence revolution may be best chance for Africa to catch-up and industrialize because continent has basic capabilities, intellectual capital which if amplified by artificial intelligence can help continent leapfrog to 4th industrialization. The basic capabilities and intellectual capital were lacking in the continent during 1st, 2nd and 3rd industrial revolutions in the continent.

Artificial intelligence can support design thinking startups by enabling them to mix the right cultures and creative ideas in teams, empower research phase by making it more observer based and automate prototyping and learning phase (Cautela et al. 2019). The informal sector innovations can also be supported since the informal inventors work in entities that have many characteristics of startups. Innovation culture is important because it celebrates and promotes inventing and innovating and programs minds for invention and innovation. Automating formal and informal invention and

innovation learning and prototyping increases productivity. While most informal sector inventors invent as individuals, teams of informal sector inventors are likely to be more successful. Informal sector inventors should try to look for other inventors to collaborate with.

Artificial intelligence can be used to support both informal and formal sector inventions and to automate invention methods. Research and development is being done to create artificial inventors which could also be created for informal sector inventors like Nderitu.

Discussion

From examined literature there is poor support for informal sector category that uses global and local knowledge, whether innovating within discipline, outside or beyond any discipline. Informal sector is not easy to support by formal support organizations as this sector doesn't fit support organizations industrial and disciplinary systems of knowledge, technology and operations. Transdisciplinarity that combines different types of knowledge for innovation is one of the promising ways to support these informal inventors.

Learning by informal inventors as well as recording their work is important as a learning, teaching and research resource to inform future invention. Writing books about informal inventors and publishing them in open source platforms under creative common license can make the knowledge widely available to society. For this to be possible support institutions should aid the process and cover some or all publishing costs. Another was of benefiting from the informal sector inventors is having university student with knowledge in related areas carry out projects that try to capture knowledge and assist this informal inventors as well as learn from them.

Conclusion

Igniting many people's imaginations is likely to lead to curiosity and generation of more novel ideas that could help in developing the illusive vision of reawakening African invention and innovation spirit. Inventors are most important critical success factor as they drive other system parts of Invention system. Informal sector invention processes are easier to understand and apply by masses compared to formal processes. However these approaches are not as effective because they are not based on theory. Connecting these informal approaches with invention and innovation theory is one way to improve them. This study made connections between informal invention approaches with

formal theories and systems.

Most educated informal sector inventors like Nderitu invent outside their disciplines through trial and error, experimenting, learning from literature they can assimilated through improvisation. Few informal sector invention activities in developing countries have been linked to invention theory and this study made some linkages. Design thinking method was proposed as one the methods that can be adapted then adopted to provide a method for informal sector inventors and innovators. Innovation support organizations should find low cost ways to better support informal sector inventors by informing or providing them with sources of knowledge and information about other institutions that can assist them.

Future research should study other African informal sector inventors and publish results in journals and books to aid systematizing informal invention knowledge, experience and artifacts; create new knowledge and connect them with invention and innovation theory. The published research would then be synthesized through literature reviews and referencing each other and other relevant research. The study's Nderitu's review is based on grey literature. It's likely the literature of other informal sector inventors is lacking, if little exists it's not written in English or are physical publications that cannot be accessed online or they are out of publication. This is not unique to Africa but to most of the developing world. However even published research on formal African inventors is small compared to that of developed countries inventors. Informal research journal publications will help change this situation by providing more reliable well thought outsources; connect informal sector activities to theory and attracting more researchers. Many researchers are attracted more to areas with some minimum of research than those without.

References

Alstott, J. Triulzi, G. Yan, B. & Luo, J. (2017). Inventors' explorations across technology domains. Des. Sci., 3(20).

Beniwal, S. (2016). Jugaad as Design, Design as Jugaad. www.academia.edu

Botha, A. P. (2019). A mind model for intelligent machine innovation using future thinking principles. *Journal of Manufacturing Technology Management*, 30(8), 1250-1264.

Brem, A. & Wolfram, P. (2014). Research and development from the bottom up: Introduction of terminologies for new product development in emerging markets. *Journal of Innovation and*

Entrepreneurship, 3(9).

Bushe, G. (2012). Foundations of appreciative inquiry: History, criticism and potential. AI Practitioner, 14(1), 8-20.

Cautela, C., Mortati, M., Dell´Era, C. & Gastaldi, L. (2019). The impact of artificial intelligence on Design Thinking practice: Insights from the ecosystem of startups. *Strategic Design Research Journal*, 12(1), 114-134. Doi: 10.4013/sdrj.2019.121.08.

Citizen TV, (2010). Aircraft maker to make a test run. https://www.youtube.com/watch?v=ujU1DjaYfs4

Cunningham, P. Cunningham, M. & Ekenberg, L. (2014) Baseline analysis of 3 innovation ecosystems in East Africa. 2014 International Conference on Advances in ICT for Emerging Regions, IEEE, 156 – 162.

Dufva, T. (2017). Movement creating knowledge through basic intention. Techne Series A, 24(2), 129–141.

Essmann, H. E. & Du Perez, N. D. (2009). Practical cases of assessing innovation capability with a theoretical model: The process and findings. 23rd annual SAIIE conference proceedings, 42-56.

Gupta, A. K. (2006). From sink to source: The Honey Bee Network documents indigenous knowledge and innovations in India. Innovations: Technology, Governance, Globalization, 1(3), 49-66.

Heeks, D. (2008). ICT4D 2.0: The Next Phase of Applying ICT for International Development, IEEE.

Igwe, P. A. & Ochinanwata, C. (2021). How to start African Informal entrepreneurial revolution? *Journal of African Business*, 22(4), 514-531.

Karanja. S. (2020). Man makes his own aircraft, hopes to fly them. Nation. https://nation.africa/kenya/counties/nyeri/man-makes-his-own-aircraft-hopes-to-fly-them-902676

Khalil-Timamy, M. H. (2002). State of science and technological capacity in Sub-Saharan Africa. African Technology Policy Studies Network.

Kraemer-Mbula, E. & Armstrong, C. (2017). The Maker movement in Gauteng province. South Africa, OpenAIR, Working Paper 6.

Kurz, J. M. (2012). Appreciative inquiry: Applied to information technology

Mambo, W. N. (2017). Adapting information technology innovations to country Context. IJCIT, 6(1), 27-31.

Mambo, W. N. (2021) Innovatively Exploring Proverbs with Transdisciplinarity. *African Journal of Applied Research*, 7(2), 137-154.

Mambo, W. N. (2022). Aligning software engineering and artificial intelligence with transdisciplinary. *Transdisciplinary Journal of Engineering & Science*, 21-34.

Mambo, W. (2023). Africa informal technology sector borrowing principles, concepts, theories, techniques and methods from other sectors. *Discovery journal*.

Manyati, T. K. & Mutsau, M. (2020). Factors that limit the development, prototyping and adoption of informal innovations in Zimbabwe: Lessons for policymakers. *African Journal of Science, Technology, Innovation and Development*.

Nakamura, Y. (2003). Combination of ARIZ92 and NM (Nakayama, Masakazu) method for the 5-th level problems. *TRIZ Journal*.

Nicolescu, B. (2010). Methodology of transdisciplinarity: levels of reality, logic of the included middle and complexity. *Transdisciplinary Journal of Science and Engineering*, 1(1), 19-38.

Nyemba, W. R. Chikuku, T. Chiroodza, J. R. Dube, B. Carter, K. F. Mhohwa, C. & Magombo, L. (2020). Industrial design thinking propelled by royal academy of engineering in Sub-Saharan African for capacity building. Procedia CIRP 91, 770–775.

Oreku, G. S. and Mtenzi, F. J. (2013). Adoption and Diffusion of Open Source in Tanzania, A Way Forward. In Cunningham, P. and Cunningham, M., (ed.) IST-Africa Conference Proceedings.

Osborn, A. (1957). Applied Imagination. Charles Scribners Sons.

Rice, X. (2010). Kenyan aviation enthusiast builds aeroplane in front yard: Gabriel Nderitu's collapsible two-seater propeller plane has been built using instructions downloaded from Wikipedia. The Guardian. https://www.theguardian.com/world/2010/oct/26/kenya-plane-homemade

Robinson, J. (2015). Kenyan unveils his home-made plane in front of crowds and TV crew… and it does not end well. Mail online. https://www.dailymail.co.uk/news/article-3137730/Kenyan-unveils-home-plane-crowds-TV-crew-does-not-end-well.html

Schleinkofer, U. Herrmann, Maier, I. Bauernhans, T. Roth, D. & Spath, D. (2019). Development and evaluation of a design thinking process to frugal production systems for emerging markets. Procedia Manufacturing, 39, 609–617.

Sharma, G. & Kumar, H. (2019). Commercializing innovations from the informal economy: The grassroots innovation ecosystem in India. *South Asian Journal of Business Studies*, 8 (1), 40-61.

Smith, C. (2010). Civilian engineering in Africa: The only way is up for young inventors. Guardian.

Tate, D. (2010). Designing transdisciplinary discovery and innovation: models and tools for dynamic knowledge integration. *Transdisciplinary Journal of Engineering & Science*, 1(1), 105-124.

Usher, A. (1929). A history of mechanical inventions. Harvard university press.

Yamamoto, Y. (2010). Kaikaku in production. Licentiate Thesis, Malardalen University. http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A319289&dswid=-3041