A Review of Proverbs in Computing and Design

Wangai Njoroge Mambo

***Abstract*— Computing and design disciplines knowledge is embedded in computers that are pervasive, used by everyone. To maximize benefits to everyone these disciplines should increase embedded indigenous research and practice knowledge like proverbs in artefacts. The study's goal was find proverb how proverbs are being applied and research that has been done in computing and design disciplines; and how it can be synthesized. Proverbs are bridges for crossing chasms between theory and practice, design and technology, cultures, disciplines and society driven by their transdisciplinarity. Transdisciplinary literature review method was used. The findings are proverbs are being applied and researched in several areas of computing and design.**

***Keywords*—computing, creativity, design, innovation, metaphors, proverbs, transdisciplinary.**

I. INTRODUCTION

Developing countries have significant proportion of their populations depending on indigenous knowledge. However indigenous knowledge has been largely ignored compared with global knowledge. Failure to make significant indigenous knowledge improvements means that systems that depend on indigenous knowledge have not been improved compared to those that depend on global knowledge. This makes a significant proportion of population not to participate in knowledge based society. Integrating local and global knowledge can provide many benefits.

Proverbs can build bridges for crossing cultural boundaries [1] in a transdisciplinary way [2]. Among definitions of culture is that it sum total of everything including knowledge and technology, a transdisciplinary perspective of culture. Disciplines, organizations and communities have different cultures that are collaboration barriers that are overcome by creativity and transdisciplinarity. Transdisciplinary nature of proverbs enables reasoning to cross cultural, disciplinary, innovation and knowledge boundaries to discover new ideas. The proverb "a proverb is a horse that can quickly carry you to discover new ideas" and "one who knows proverbs gets what one wants" are two African proverbs that support transdisciplinary point of view by opening disciplinary boundaries to find ideas and solutions. Proverbs are knowledge management and representation languages with similar characteristics to artificial intelligence (AI) languages as they both represent and manage human knowledge but for different systems. Representation languages are widely used in Artificial intelligence especially in field of expert systems to represent ideas and objects [3]. The characteristics of good representation languages are: should be capable of solving the problems, use simple representation conventions to produce easy to understand expressions capable of representing whatever needs to be represented [3]. Proverbs use few and simple natural language concepts combining them in familiar simple ways, characteristics that make proverbs simple constructs. Because proverbs are simple they can be combined in many different ways resulting in different systems of constructs that can be used for different purposes. Any knowledge such themes, advice, topics can be summarized and represented as a short proverb expression similar to theories about phenomena that are usually represented as short expressions yet they are powerful. It's possible to model theories with simple proverbial expressions.

Proverb is a language familiar to all members of society and representing technical knowledge in proverbial form can enable it to diffuse faster through society. Representing knowledge in proverb form increases knowledge adoption compatibility and trialability. Trialability aligns knowledge with social values, beliefs and experiences. Adoption compatibility requires aligning innovation with society's world view and trialability enables trying knowledge and innovations on limited basis before adopting [4]. This makes it easy to perform thought experiments and simulations.

Indigenous knowledge was used by new Asian industrializing nations to catch up by building indigenous technology research, development, science and innovation skills; and capabilities. More countries industrialized by studying industrialization paths of already industrialized countries that were most appropriate for them, then adapted and modified paths to their development context than those that tried to invent their own industrialization paths. African countries are more likely to industrialize by learning paths that exemplar industrialized countries that faced similar challenges to theirs used and then indigenize those paths. Several studies indicate failure to leverage indigenous knowledge and integrate it with global knowledge is the major bottle neck to African education, technology, industrialization and development catch-up [e.g. 5, 6]. Advances of technical disciplines like computing disciplines are also hindered by indigenous knowledge leverage bottleneck. Proverbs are a natural mechanism for storing society's frequently used knowledge and solutions that can be quickly recalled for reasoning and problem solving. They provided society without writing system with ways of memorizing knowledge [7] and creatively applying it. Although all African societies today have writing systems affordability of written material is still a challenge to some people with many other priorities.

Information systems (IS) [8], artificial intelligence (AI) [9] and proverbs [2] are transdisciplinary. Their transdisciplinarity enables different paradigms to be integrated by unifying and transcending their knowledge and experiences [10] between, beyond and across them [11]. Transdisciplinarity AI [9] builds bridges and integrates

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Received: 29-06-2023 Revised: 11-09-2024 Accepted: 20-12-2024

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DOI:https://doi.org/10.4038/icter.v17i4.7283

knowledge across chasms between different organizations, disciplines, cultures and societies [12]. Chasms are less explored gold mines for discovering novel ideas and innovations. Chasms contain different types of distances [13] that can be bridged by people separated by knowledge, experience and skill distances collaborating to innovate.

National and cross cultural research influence information systems culture which in turn influences technology development [14], which makes studying culture at national and disciplinary levels important. Organizational and IS culture influence: the way information systems are developed, adopted and diffused, how information technology (IT) is used, its outcomes and IT strategy [14]. Computing disciplines are siblings with IS, so their cultures share many similarities. Their organizational and computing cultures therefore interact with each other and are influenced by national culture. Proverbs is a widely used genre for all activities in Africa and some other societies whose cultural elements can be codified for cultural oriented IT development, adoption, diffusion, management and strategy.

Computing systems are being developed for people including those at low income levels, some of who predominantly use indigenous knowledge. One way to improve productivity of these people is to improve indigenous knowledge and indigenize computing systems they use. Proverbs are used for evaluation in development projects by local people [15] and in all phases of information systems research by researchers [16]. Finding how proverbs are applied in computing and design disciplines present opportunities for borrowing applicable knowledge, techniques from each other. The Internet of Things continues automating everyday things and activities, it requires embedding indigenous knowledge for things used by ordinary people. Some technology informal sector developing segments predominantly use indigenous knowledge including proverbs. The study research objectives are to find proverb research that has been done in computing and design disciplines, and to synthesize it.

II. RELATED WORK

A related study that used literature review and qualitative data analysis research methods found proverbs could help IS professionals develop local technology solutions for local people, collaborate with local people who predominantly use indigenous knowledge, expand coverage and advance IS proverb research [16]. This research is broader than [16] by covering proverbs globally for computing and design disciplines and extends proverb application beyond African proverb information systems human application to cover all applications in these disciplines. Iyamu (2021) study focused on concept and theory development while this study's differs by focusing on proverb knowledge creation and application.

III. METHODOLOGY

Transdisciplinary literature review research method was selected because it is enables crossing disciplinary boundaries and can be used in scarcely researched areas by including related areas [17]. Transdisciplinarity enabled crossing, moving between, beyond computing and design disciplines to proverb domain and vice versa [11]. Transdisciplinary moves and oscillates between disciplines, what is outside them and non-systematized knowledge [18] by combining knowledge from multiple sources for multiple purposes [19] and allowed literature synthesis.

Computing disciplines overlap with each other and have a lot in common [e.g. 20]. Design discipline was included because it's widely applied and studied by computing disciplines. Computing disciplines initially borrowed design theory from design discipline then evolved the theory. Published literature using one or two proverbs in one sentence of a publication is vast, so selected sample was limited to papers with more proverb content and significance to avoid reviewing large number of articles with limited value.

The search was done by Google scholar using concatenation of strings proverb, software engineering, artificial intelligence, information systems, information technology, computer engineering and design. Search started by selecting papers with proverbs in their titles, abstract and keywords. The abstract was read to determine if it was dealing with proverbs in a computing or design discipline, or their subfields or topics. Adobe or browser search was used to locate proverb string in paper to determine whether proverb content was significant for further consideration. Papers without significant proverb contribution were excluded. Remaining papers were read and only papers judged as relevant and with significant proverb application were included.

IV. LITERATURE REVIEW AND FINDINGS

The results organized according disciplines are presented in following sub sections.

A. Proverbs in information systems and Technology

Google search found few IS and IT proverb papers. For example one on indigenizing and inventive exploration [16] and another for automating proverb applications with ontology [21], indicating little proverb research and applications in these disciplines. Proverbs can indigenize, expand African inventiveness, increase collaboration, invigorate heritage and IS research making research easier to use by indigenous candidates in classrooms and field work [16]. Proverbs can indigenize research to varying degrees in all disciplines, since disciplines share subsets of research components.

IT innovations can be adapted with proverbs to make the innovations suitable for local context which was demonstrated by adapting Design thinking extreme programming method to improve its adoptability's: relative advantage, compatibility, observability and trialability [22]. Proverbs are a micro architectures language that can be used to design adoption structure and then fit that structure with innovation knowledge. Software patterns are similar and serve same functions as proverbs but for different communities: society and software developers respectively. Their similarity enables analogy inspired methods to be used to transfer knowledge between the two domains. Pattern format was used to represent proverbs [22] to increase applicability of proverbs to computing technology development. They were used to demonstrate how informal sector innovators could have invented mobile phone beeping innovation [23] within field of information communication technology for development (ICT4D). They can be used to

connect indigenous technology developers at the bottom of pyramid with fields for development such as ICT4D, Artificial intelligence for development, design for development and knowledge management for development.

B. Knowledge and methods.

Software and system development methods are IS research methods [24, 25] and reverse software and system development methods are research methods. Proverbs have been used to indigenize software development methods [21] and research methods [16]. This is especially necessary for international research and development projects with international and local community stakeholders as project beneficiaries at intersection computing and society.

Proverb search has been automated with multidimensional search through a concept graph linking proverbs and related concepts [21]. For example the proverb puffader (snake) that doesn't fly has caught hornbill (bird) the ontology graph has node Horn bill related concepts bird, tree, nest, flying, wings.

Improvisation's ability to deal with unstructured problems was used to explore music as information systems [26]. Proverbs also use improvisation to deal with unstructured problems making analogy applicable to exploring IS solutions as possible proverb problem solutions and vice versa. Cognitive psychology models human thinking as information processing system [27]. Viewing proverbs as ISs and cognitive information processing systems can be used to model AI proverb reasoning systems. Pancomputationalism understands and models universe and everything in it as a kind of computer and computation device represented as network of processes at different levels of reality [28]. According to pancomputationalism the universe is system of systems, an information processing supra system consisting of parts that are information processing systems. The two types of modeling provide higher frameworks for considering other systems as kinds of computing systems within transdisciplinarity paradigm.

C. Proverbs, Software Engineering and Artificial Intelligence.

AI synthesizes and models heterogeneous knowledge creating transdisciplinary knowledge [12] for example synthesizing proverbs, research and innovation knowledge. AI doesn't privilege any knowledge: human, animal, plant or non-living thing but selects knowledge that works best. Transdisciplinary AI can automate and learn wisdom from different spheres of life, integrate sociology, psychology, proverbs [29], support alliance between economics and engineering [9], computing and indigenous knowledge.

Transdisciplinarity crosses, moves between and beyond knowledge, technology, disciplinary, organizational and societal boundaries [11] by for example combining IS, AI and software engineering. Metaphoric transdisciplinary crossing can be enabled by relating similar objects from each participating discipline's boundaries, moving beyond boundaries by relating disciplinary objects and objects outside any discipline like future or imaginary objects, moving between boundaries by relating boundary objects to create metaphors.

Funny proverbs were generated from existing proverbs by changing the last character of a Japanese proverb written in Chinese alphabet by using a laughing framework and the author believed the research could be useful for friendly communication and entertainer robots [30]. The last Chinese proverb character corresponds to an English proverb phrase in Roman alphabet. Generating English funny proverbs can be done by polysymbolism where proverb symbol concepts are substituted with other concepts [31] or by changing proverb phrases. The concepts can be connected to create an ontological graph. Funny proverb generation is evidence that creativity and improvisation can transform proverbs and sayings into other useful forms.

Proverbs can be translated into a system of visual symbols for designing textile [32]. Physical symbol system hypothesis is necessary and sufficient condition for system to be capable of general intelligent action [33]. A symbol substitution technique [2] and genetic search based software engineering (GSBSE) [34] are used for transdisciplinary technology development. A design oriented physical symbol system for SE can be created by integrating GSBSE, symbol substitution techniques and proverbial symbol structures. Unifying proverbs and technology development is unconventional and can lead to innovation. Proverbs and knowledge presented as proverbial principles, observations, axioms, and assumptions are used in software development [35]. Non software domain knowledge, sayings and innovation principles can be presented in proverbial form to make them compatible with proverb reasoning

A Natural language processing algorithm was used to experiment with matching Italian, English proverbs and metaphors using proverb concepts, nouns and domains [36] enabling humans to better apply proverbs than common practice of proverb text automation [29]. Proverbs connect domains and disciplines using metaphors enabling integration, crossing of disciplines and cultures [36]. Computers can be taught metaphors [37] including metaphoric proverbs. Human computation system can enhance AI and human systems collaboration by creating innovation graphs that connect AI systems, people and proverbs [38]. Thesis proverb too many cooks spoil the broth and its anti-thesis many hands make work light were used to explore how human computation can maximize team collaboration synergy inspired by superorganism systems [39]. Knowledge flowing through an innovation graph consisting of human and AI system nodes can be used generate novel ideas and transform ideas into innovations. It's the way human innovation networks create innovations.

Advice for developing expert systems is proverbial, application success depends on context, because both proverbs and expert systems are developed from individual experience and different people have different experiences [40]. Best practices and expertise can be represented as proverbs and proverbial expressions for ease of adoption; and sharing by community of researchers and practitioners. Expert system knowledge folklore is produced by practitioners developing expert systems, once knowledge becomes well understood researchers develop theories contributing to maturity of the field [41] similarly software engineering represents its knowledge in proverbial expressions and proverbs [35]. Proverbs can be systematized by applying theories from other disciplines like psychology and business as was done using structuration theory [16], Maslow motivation hierarchy and self-determination theories [29]. Borrowing and creating proverb technical

theories is necessary to make proverbs a social technical language to supplement mostly social theories dominated proverb domain.

Expert system development knowledge, experience is proverbial [40] and similar to proverbs is created by capturing and transforming human expertise into a form suitable for problem solving and technology development. Novel features were designed and used in an experiment for metaphor detection in fiction and academic genres by associating images with proverbs annotated with metaphors [42], enabling proverb knowledge visualization [43]. Synectics problem solving and creativity drives brainstorming through proverb metaphors to enable visualization of technology and its development process [44]. Visualization enables better understanding of abstract entities.

The proverb if you want to go fast go alone, if you want to go far go with others was used to illustrate how an organization can organize development of advanced Big Data and machine learning systems [45]. Applicability of this proverb advice is due to need for agreement on collaboration process by organization members or organizations partnerships negotiating and signing contracts. Once collaboration starts groups of collaborators integrating and aligning their efforts and knowledge creates synergy increasing productivity. Individual is likely to start quickly and move ahead quickly in beginning while collaborators will start slowly then move faster and overtake individual. Individuals are likely to do better in small and simple projects while teams and organization in large and complex projects.

Filho et al. (2020) cardiology machine learning study used metaphor of horse and jockey, the doctor is a jockey and machine learning the horse to illustrate relationship between doctors and machine learning. The horse-jockey metaphor is used by the African proverb "A proverb is horse that can quickly carry you to discover new ideas". Proverb and horse in this proverb are symbols that can be substituted with other concepts. The proverb can be applied in AI by substituting machine learning with proverb symbol creating Filho's metaphor. This is an example of a proverb being used as an invention heuristic as shown by Polya. The polysymbolized proverb demonstrates power of proverb applications is limited by creativity applied [2]. The metaphor and horse proverb can be generalized to metaphor expert is jockey and effective means is the horse.

The proverb it takes a village to raise a child was used as guide to show how organizations should build analytics culture by everyone contributing to its growth [47]. Application of proverb mapped child to analytics culture and village to organization, creating metaphors that enabled everyday knowledge transfer to an advanced technical activity. Raising a child and polysymbolized horse proverb hints at potential for wider cross cultural applicability of proverbs in computing by people from different cultures in areas like data science by global researchers as authors of two papers were non Africans but applied African proverbs. Countries that widely speak foreign languages use the foreign language proverbs in their cross cultural communication. Knowledge based systems proverb reasoning, expertise mechanisms and knowledge bases must meet same expertise requirements as those of professional experts to qualify as expertise [3]. Proverb techniques and methods must similarly have strengths and present opportunities in some areas over disciplinary techniques and methods to become part technical activities toolkit. Iyamu (2021) research approach provides insights on ways of carrying proverb research in technical disciplines.

An AI game stored proverbs and knowledge in game's knowledge base and presented player with five unrelated words that may include proverb words and game system uses knowledge base to find solutions that contain the five words thereby determining whether players answer was correct [48]. Semeraro et al. (2012), gives an example if a player is presented with Newton and doctor, the solution is apple as Newton discovered gravity when apple fell on his head and the proverb an apple a day keeps doctor away. Another AI game an artificial player is given five words that may include proverbs and player provides related but different words [49]. The two games are forms of puzzle solving or riddling that combine proverbs with other elements. These games, funny proverb generation and proverb polysymbolism provides insights on ways proverbs can be used in computing entertainment, learning, riddling games and creativity applications.

A natural language processing (NLP) algorithm was created to generate Hindi story tittles from proverbs in those stories [50]. Another NLP machine learning algorithm analyses understands and retrieves a specific proverb in five Indian languages [51]. Advancement of NLP and machine learning will enable further automation of proverb reasoning and applications. Large language models and generative AI may open new frontiers of proverb applications.

Similar to AI, proverb application can make progress in technical applications by not respecting knowledge boundaries but by focusing on whether the results produced work or not. Disciplinary research and application of proverbs has been rigid, bounded by disciplinary boundaries. AI combines knowledge of humans with that animals and plants to create algorithms with human like intelligence. An example is combining knowledge of ants and humans to create intelligent foraging algorithms that guide researchers to places they are likely to find useful knowledge and researchable topics.

D. Proverbs and research.

The proverb one who dwells under a tree knows what the ant eats, teaches importance researcher or practitioner dwelling in environment of phenomena of interest, in order to know it better. Another proverb the knife knows the inside of Coco yam emphasizes importance of using right methods, tools, instruments and skills when researching or practicing with phenomena. Another proverb research is asking plant questions and plant answering, uses metaphor of plant as expert (who answers questions) and researcher as learner or researcher as interviewer and plant interview.

Indigenous knowledge is basis of local social and technology activities decision making processes used for knowledge creation by researchers, practitioners and local project beneficiaries to integrate research, indigenous knowledge and global knowledge [52]. This kind of integration is critical success factor for local innovation. It requires crossing several fields of knowledge which may require transdisciplinary methods. Proverbs are one component of indigenous knowledge that can be easily communicated and shared. Social technical decision making

processes that enable communication and new knowledge creation by local communities that predominantly use indigenous knowledge can be beneficial to computing fields for development.

E. Proverbs and Design.

Proverb inspired design uses proverbs inspiration to design textile [32] while fashion inspired design adopts a transdisciplinary attitude by stepping from fashion design into culture to apply indigenous proverbs to design [53]. Computing can support proverb inspired design by developing new or adapting existing human computation, computer aided invention and design tools.

Cultural inspired design (CID) innovation creates novel products through user's eyes by making design and culture complementary [54]. African white students, lecturers and designers spontaneously draw on African proverbs and metaphors for inspiration to design while African black students only do so if required [55]. One possible explanation is African white students use explicit proverb design knowledge that is easy to communicate while black students use tacit proverb design knowledge that is difficult to communicate in formal language. The number of papers found by this study on proverbs in design indicates there are few practitioner and researcher papers globally. This leads to little improvement in proverb design research which indigenous knowledge artisans at bottom of pyramid require. This is due to technical professionals lacking indigenous technical mind-set, deskilling of past indigenous skills, capabilities and little published literature on indigenous methods. CID education catalyses industrial design formal and informal sectors: creating jobs through actualizing indigenous knowledge in product development [56]. Analogy inspired design includes all inspired design domains like CID, bioinspired design and emerging artificial intelligence inspired design. Cultural oriented design can be promoted by applying indigenous product development design mediation model to combine values, norms and beliefs with symbols and signs; and providing designers with locally designed materials, lists of social practices (including proverbs), emotional, technology, design factors [57]. This model can be adapted for symbolic transdisciplinarity and bioinspired artificial intelligence design of algorithms and robots. Culture is cumulative sum total of all knowledge, technologies and experiences of a community, a vast knowledge base that can be used for cultural inspired design. Cultural algorithms have been designed using genetic algorithms [58]. Cultural genetic algorithms can be used to automate cultural inspired design domains like proverb design.

Cultural innovation as cultural species can learn from other cultures species improving itself by introducing novel elements [59]. A cultural learning algorithm can be restricted to learn from proverbs of other cultures. Cellular automata can also be used to implement cultural algorithms as societies tend to form cell like structures and each culture tends to be influenced more by near cultures than distant ones. Nearness includes virtual nearness enabled by telecommunication and Internet technologies like social media.

ARIZ innovation algorithm [60] and NM innovation [61] and conjecture analogy design science methods [62] use analogy inspired design by using problem object to search for similar natural and human-made object solutions that can be improvised to invent. In absence of better proverb methods, indigenous technology inventors, innovators and developers can use ARIZ algorithm, NM and conjecture methods and apply them to solve proverb human-made systems problems.

Combining CID model and conjecture method then applying combination to proverbs can be used to invent. CID could use proverbs as cultural eyes and conjecture method to conjecture for example applying proverbs is designing and designing is applying proverbs. The proverb "a proverb is horse that can carry you quickly to discover new ideas", can be used to transfer design and method knowledge to proverb domain and vice versa. This could create proverbs like design is a horse that can aid you to quickly invent and metaphors like Filho machine learning is a horse and doctor is a jockey. This supported by Polya finding that proverbs are invention heuristics. These simple examples of CID and conjecture method applied to proverbs and metaphors are evidence proverbs can be used to invent.

F. Proverb application examples.

Knowledge based repositories are used to create and manage expertise sources in specific sectors of a country. An example is agricultural knowledge base repository based on ontology of concepts for sharing knowledge [63]. Establishing a design proverb repository can be used collect data to create design datasets. A knowledge base integrated with an idea bank can to generate, exchange, refine ideas for innovation, combined with innovation strategy would enable creating holistic innovation solutions [64]. Continuous improvement of stored proverb knowledge and the knowledge base mechanisms can increase value system delivers to its users.

New proverbs are created using abstract old proverbs templates [65]. Deriving templates from existing proverbs by abstraction and symbol generalization can simplify and systematize process of creating of new proverbs. Templates can annotate repository knowledge for knowledge based search and AI aided reasoning. Action templates can be used to coordinate atomic behaviour of multiple individuals collaborating through complex atomic actions [66] enabling conscious, collaborative proverb creation.

Proverbs a stitch in time saves nine and the hidden serpent grow large [22], mirror software engineering strategy of discovering errors as early as possible during development lifecycle. Software engineering is knowledge based activity. Major cause of software engineering errors is cognitive failures than can be solved by applying human error theory [67]. Human error theory is psychological theory that explains why, when and how humans make errors. A method based on theory for preventing software engineering errors sequence of steps are developers: acquire knowledge of human error mechanisms and how to prevent them, they are trained on cognition self-regulation and continuous improvement [67] An error made during requirements engineering that makes it through acceptance testing to the customer can bring an organization computing system or a software ecosystem down. There are many examples in literature of errors made during the early stages of software engineering life cycle. For example Therac-25 resulted in cancer patients receiving deadly radiation overdoses due to software error that was not discovered before delivery of

machine [68]. Errors are serpents that grow larger as you move from requirements engineering to design, implementation, operations and maintenance, fixing (stitch) in time can prevent disaster The proverb knowledge is power can be used to empathize importance increasing testing knowledge of testers. It can also encourage adoption of artificial intelligence knowledge based systems by inference AI is knowledge machine that increases power of those who use it.

G. Findings.

Findings are computing, design and proverbs are complementary. Design thinking and computing thinking can applied in proverb applications. Just as everyone designs and can design everyone processes information by design thinking and computational thinking respectively [69] which are complementary with proverb reasoning. In addition computing can further complement proverbs by automating proverb activities. Proverbs in turn can be used to support problem solving, reasoning, creativity, innovating and inventing in design and computing. Academic theories and analogy inspired design method are being used to push proverb research and practice boundaries to new frontiers.

Proverbs are being applied is several areas of computing and design. In information systems and information technology they have been proposed for inventing and indigenizing technology. Proverbs provide research advice and indigenous insights that are useful to technology researchers and practitioners. In design proverbs have been used to design textiles. They can be substituted for indigenous knowledge (IK) component in design models and methods that use IK. Proverbs are being used in artificial intelligence games and natural language processing which can be catalysed by large language models and generative AI. Software engineering uses proverbs as reasoning heuristics.

V. CONCLUSIONS

There is little proverb research in artificial intelligence, software engineering, information systems, information technology and design. Combining research in these disciplines creates a bigger knowledge base to advance technical proverb research. Computing can complement proverb domain by automating and providing inspiration for proverb research and practice. Proverb domain can in return complement computing and design by providing indigenous reasoning systems, solutions and analogy inspired design elements.

The study found applying academic theories, transdisciplinarity and analogy inspired design methods has been used to push boundaries of technical proverb research and practice. A computer science thesis and one IS proverb research paper applied global academic structuration theory, Maslow motivation hierarchy of needs and self-determination theory to extend proverb knowledge boundaries. Some global techniques share some similarities with specific proverbs which enables borrowing knowledge from each other. Creating a database table with proverb and similar technique columns can aid collaborative exploration of how to transfer knowledge between techniques and proverbs through collaboration using means like Ranasinghem et al. (2008) action templates

Future research should be carried to find other academic theories, models and processes that can be used to systemize proverbs and extend proverb research towards making proverbs a formal knowledge based language. Further literature review should be done to find research in other computing related disciplines not covered by this study.

ACKNOWLEDGMENT

No acknowledgement.

APPENDIX A

ACM – Association of computing machinery
ARIZ – Algorithm for inventive problem solving
TRIZ – Theory of Inventive Problem Solving
CID – Cultural Inspired Design
IEEE – Institute of Electric and Electronic, Engineers
NM - Nakayama Masakazu.

REFERENCES

[1] Buja, E. (2018). Proverbs as a Means of Crossing Cultural Borders, Acta Universitatis Sapientiae, Philologica, 10(2), 85–97.
[2] Mambo, W. N. (2021). Innovatively Exploring Proverbs with Transdisciplinarity, African Journal of Applied Research, 7(2), 137-154.
[3] Jackson, P. (1999). Introduction to Expert Systems, 3rd Edition, Addison-Wesley.
[4] Rogers, E.M. (1995). Diffusion of Innovations, Free Press.
[5] Bwisa, H. M. (2005). The role of Indigenous Entrepreneurship in Industrialization and Poverty Alleviation in Developing Nations: The Case of Kenya, Proceedings of JKUAT Scientific and Industrialization Conference.
[6] Hooli, L. J. & Jauhiainen, J. S. (2018). Building an Innovation System and Indigenous Knowledge in Namibia, African Journal of Science, Technology, Innovation and Development, 10(2), 183-196.
[7] Ezeanya-Esiobu, C. (2019). Indigenous Knowledge and Education, Springer.
[8] Kroeze, J. H. Travica, B. & Zyl, I. V. (2019). Information Systems in a Transdisciplinary Perspective: Leaping to a Larger Stage, Alternation Special Edition, 24, 9-47.
[9] Mariotti, S. (2021). Forging a New Alliance between Economics and Engineering, Journal of Industrial and Business Economics.
[10] Pohl, C. (2010). From Transdisciplinarity to Transdisciplinary Research. Transdisciplinary Journal of Engineering & Science, 1, 65-73.
[11] 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.
[12] Anum, L. Lodhi, S. A. & Ahmed, K. (2018). Knowledge Transcendence: Strengthening Knowledge Management Efforts on Modeling Transdisciplinary Knowledge using Artificial Intelligence, International Journal of Computer Science and Network Security, 18(6), 139-147.
[13] Parjanen, S. (2008). Distance and Proximity as Source of Innovation in Regional Innovation Processes, Conference on Regional Development and Innovation Processes.
[14] Leidner, D. E. & Kayworth, T. (2006). A review of Culture in Information Systems Research: Toward a Theory of Information Technology Culture Conflict, MIS Quarterly, 30(2), 357-399.
[15] Local researchers & Easton, P. (2004). Participatory Management and Local Culture: Proverbs and Paradigms, in Indigenous Knowledge: Local Pathways to Global Development, Knowledge and Learning Group, World Bank, 128-131.
[16] Iyamu, T. (2021). The Role of African Proverbs in Advancing Information Systems Research, The African Journal of Information Systems, 13(4), 476-492.
[17] Montuori, A. (2013). The Complexity of Transdisciplinary Literature Reviews. Complicity: An International Journal of Complexity and Education, 10(1–2), 45–55.
[18] Brandão, C. A. (2010). Transdisciplinarity: Yesterday and Today, in Pena, S. D. (Eds.) Themes in transdisciplinary research, 7-19.
[19] Lebow, D. G. (2018). A social Machine for Transdisciplinary Research. Informing Science: the International Journal of an Emerging Transdiscipline, 21, 201-217.

[20] ACM/AIS/IEEE, (2005). Computing Curriculum 2005, Joint task force for computing curriculum.
[21] Zhitomirsky-Geffet, M. Prebor, G. & Bloch, O. (2017). Improving Proverb Search and Retrieval with a Generic Multidimensional Ontology, Journal of the Association for Information Science and Technology, 68(1), 141–153.
[22] Mambo, W. N. (2017). Adapting Information Technology Innovations to Country Context, IJCIT, 6(1), 27-31.
[23] Mambo, W. N. (2020). Designing Per-Poor System of Innovation Proverbs, Inkanyiso, Jnl Hum & Soc Sci, 12(2), 212-229.
[24] Nunamaker, J. F. Chen, M. & Purdin, T. (1991). Systems Development in Information Systems Research, Journal of Management Information Systems, 7(3), 89-106.
[25] Hasan, H. (2003). Information systems development as a research method, Australasian Journal of Information Systems, 11 (1), 4-13.
[26] Michalec, L. & Banks, D. A. (2004). Information Systems Development Methodologies and all that Jazz, Issues in Informing Science and Information Technology, 227-235.
[27] Russel, S. & Norvig, P. (2010). Artificial Intelligence a Modern Approach, 3rd Edition, Prentice-Hall.
[28] Eden, A. H. (2011). Some Philosophical Issues in Computer Science, Minds & Machines, 21(2), 123–133.
[29] Omolaoye, V. A. (2020). Proverb Representation using Semantic Technologies: A Case Study of Nigerian Yoruba Proverbs, MSc Computer Science thesis, Namibia University of Science and Technology.
[30] Yamane, H. & Hagiwara, M. (2010). A Funny Proverb Generation System Based on Sukashi, In International Conference on Artificial Neural Networks, Springer, Berlin, Heidelberg, 368-377.
[31] Wanjohi, G. 1997. The Wisdom and Philosophy of African Proverbs, Paulines Publications.
[32] Vigbedor, D. Gbadegbe, R. S. Adja-Koadade, M. & Agra, F. (2016). Ewe Proverbs—A Source of Imagery for Textile Designs. Arts and Design Studies, 46, 42-66.
[33] Newell, A. (1980). Physical Symbol Systems, Computer Science Department. Paper 2471.
[34] Harman, M. Jia, Y. Langdon, W. B. Petke, J. Moghadam, I. Yoo, S. & Wu, F. (2014). Genetic Improvement for Adaptive Software Engineering, SEAMS '14, ACM.
[35] Paulk, M. C. (1997). Software Process Proverbs. Crosstalk: The Journal of Defence Software Engineering, 10(1), 4-7.
[36] Özbal, G. Strapparava, C. & Tekiroglu, S. (2016). Prometheus: A Corpus of Proverbs Annotated with Metaphors, In Proceedings of the Tenth International Conference on Language Resources and Evaluation, 3787-3793.
[37] Levy, O. & Markovitch, S. (2012). Teaching Machines to Learn by Metaphors, Proceedings of the Twenty-Sixth AAAI Conference on Artificial Intelligence, 991-997.
[38] Purvis, L. & Hardas, M. (2013). Innovation via Human Computation. In Handbook of Human Computation, Springer, 247-254.
[39] Michelucci, P. (2013). Organismic Computing, In Handbook of Human Computation, Springer, 475-501.
[40] Will, R. P. & Hardaway, D. E. (1994). Advice for Building Expert Systems: Precepts or Proverbs? INTERFACES 24, 24(6), 79-81.
[41] Shaw, M. & Garlan, D. (1996). Software Architecture: Perspectives on an Emerging Discipline, Prentice-Hall.
[42] Özbal, G. Strapparava, C. Tekiroglu, S. & Pighin, D. (2016). Learning to Identify Metaphors from a Corpus of Proverbs, In Proceedings of the 2016 Conference on Empirical Methods in Natural Language Processing, 2060-2065.
[43] Özbal, G. Pighin, D. & Strapparava, C. (2019). A Proverb is Worth a Thousand Words: Learning to Associate Images with Proverbs. CogSci, 2515-2521.
[44] Bertoncelli, T. Mayer, O. & Lynass, M. (2016). Creativity, Learning Techniques and TRIZ, Procedia CIRP, 39, 191 – 196.
[45] Filho, E. Fernandes, F. Soares, C. Seixas, F. Dos Santos, A. Gismondi, R. Mesquita, E. & Mesquita, C. (2020). Artificial Intelligence in Cardiology: Concepts, Tools and Challenges - "The Horse is the one who Runs, You Must Be the Jockey", Arq Bras Cardiol, 114(4), 718-725.
[46] Polya, G. (1985). How to solve it? A New Aspect of Mathematical Method, Princeton University Press.
[47] Glasgal, R. & Nestor, V. (2020). Data Governance, Data Stewardship, and the Building of an Analytics Organizational Culture, Big Data on Campus: Data Analytics and Decision Making in Higher Education, 122-148.
[48] Semeraro, G. de Gemmis, M. Lops, P. & Basile, P. (2012). An Artificial Player for a Language Game, IEEE Intelligent Systems, 27(05), 36-43.
[49] Coffrini, A. Monica, S. & Bergenti, F. (2021). On the Design of an Artificial Player for a Popular Word Game, In CILC, 122-132.
[50] Jain, L. & Agrawal, P. (2018). Sheershak: An Automatic Title Generation Tool for Hindi Short Stories, ICACCCN2018, IEEE, 579-584.
[51] Reddy, M. Savant, M. Reddy, V. Savant, M. Kulkarni, S. & Rudrappa, N. (2022). Using Machine Learning Algorithm for Proverb Retrieval and Expansion for Indian Languages, IEEE, 244-248.
[52] Lodhi, M. S. & Mikulecky, P. (2011). Motives and Modes of Indigenous Knowledge Management. In Proceedings of the 2nd International Conference on Urban Sustainability, Cultural Sustainability, 89-94.
[53] Mchunu, K. (2017). Preparing Fashion Students for a Socially Engaged University Project through Zulu Proverbs, The Design Education Forum of Southern Africa, 169-180.
[54] Moalosi, R. Popovic, V. & Hickling-Hudson, A. (2006). Culture driven product innovation. International Design Conference, 573-578.
[55] Costandius, E. (2007). An Exploration of the Use of African Proverbs and Metaphors in a Visual Communication Design Course, Research Paper, PhD dissertation, University of Western Cape.
[56] Kashim, I. B. Ogunduyile, S. R. & Adelabu, O. S. (2011). Culturally Inspired Design Education: A Nigerian Case Study, Industrial Design - New Frontiers, InTech, 81-98.
[57] Moalosi, R. Popovic, V. & Hickling-Hudson, A. (2007). Product Analysis based on Botswana's Postcolonial Socio-Cultural Perspective. International Journal of Design, 1(2), 35-43.
[58] Reynolds, R. G. (1994). An Introduction to Cultural Algorithms, in Proceedings of the 3rd Annual Conference on Evolutionary Programming, World Scientific Publishing, 131–139.
[59] Kuo, H. C. & Lin, C. H. (2013). Cultural Evolution Algorithm for Global Optimizations and its Applications, Journal of Applied Research and Technology, 11(4), 510-522.
[60] AltShuller, G. S. (1999). The innovation algorithm; TRIZ systematic innovation algorithm and technical creativity, translated by Rodman S. and Shuylak L. Technical innovation center Inc.
[61] Nakamura, Y. (2003). Combination of ARIZ92 and NM (Nakayama, Masakazu) Method for the 5-th level problems, TRIZ Journal.
[62] Gero, J. S. (2000). Research methods for design science research: computational and cognitive approaches. Proceedings of ANZAScA.
[63] Walisadeera, A. I. Ginige, A. Wikramanayake, G. N. (2015). Developing a Community-Based Knowledge System: A Case Study using Sri Lankan Agriculture. The International Journal on Advances in ICT for Emerging Regions, 8(3).
[64] Wijesinghe, C. Hansson, H. Ekenberg, L. (2022). User Acceptance of a Novelty Idea Bank System to Reinforce ICT Innovations: Sri Lankan University-Industry perspective. International Journal on Advances in ICT for Emerging Regions, 15 (1).
[65] Kipury, N. (1983). Oral literature of the Maasai, East African Educational Publishers.
[66] Ranasinghem R. A. Madurapperuma, A. P. & Kodikara, N. D. (2008). Foraging in a Grid World Using Action Templates, The International Journal on Advances in ICT for Emerging Regions, 1(1), 24 - 32.
[67] Huang, F. & Liu. B. (2017). Software defect prevention based on human error theories. Chinese Journal of Aeronautics, 30(3), 1054–1070.
[68] Zhivich, M. & Cunningham, R. K. (2012). The Real Cost of Software Errors. IEEE Security & Privacy Magazine, 7(2), 87–90.
[69] Li, P. & Schoenfeld, A. diSessa, A. Graesser, A. Benson, L. English, L. & Duschl, R. (2020). Computational Thinking is More about Thinking than Computing. Journal for STEM Education Research, 3.