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Innovation by invitation? A hybrid developmental design model for stirring co-creation in socio-technical continuums

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Abstract

This paper proposes a hybrid developmental Design model for innovative research, practice and learning in complex socio-technical systems by combining topical theories and methods. It begins by challenging the problem of exclusive Design approaches and typical Design models which use centralised development and beneficiation. The model asks Designers to rethink their future role and relinquish control via a Participatory Design approach where Designers are responsible for demystifying the value impact of Design through a process of ongoing engagement (Lasky 2013, p. 24). The model's framework combines three Design theories that have common themes: 'Socio-Technical Systems Design', 'Appropriate Technology' and 'Design for Sustainability'. Each theory is briefly explained for what it offers and where it is deficient. The framework is then reinforced where each weakness is supported by the strength of another theory. All three theories point towards the need for a deeply empathic understanding of ecological contexts and their constituents and the need for cross-sectorial, trans-disciplinary integration. This application outputs a series of developmental socio-technical maps across the social levels; micro (individual, tacit knowledge), meso (organisational, embedded knowledge) and macro (social-systems, explicit knowledge) through identifying project relevant values/capitals that are not usually or thoroughly considered (natural, social, financial, manufactured, cultural, political, human, digital) and acknowledging their existing/potential connection as knowledge being/to be brokered. This mapping is based on a Participatory Action Research Framework developed by Nogueira *et al.* (2019). It offers a starting point for innovative engagements and a means to guide and track development throughout a continuum of integrated Socio-Technical Systems Design (Hussain *et al.* 2012, p. 91; Bellon 2001, p. 9). The model is positioned at the intersection of Design Research, practice and education. It renders a way for Design research and practice through a transparent lens of open evaluation which simultaneously provides an educational platform for knowledge and technology transfer. It not only motivates that sustainable innovation is driven by Design as a change agent but is fuelled by knowledge transfer within its context (Mumford 2006, p. 336). The paper concludes by pointing a spotlight to the writing on the wall; that the path of inclusive Design offers profound understandings of the ecologies that Design aspires to function within. The theoretical solutions and pilot example proposed in this paper signals a needed transfer of this application to educational curricula and industry training. Collaboration to further define these questions would be novel. Recommendations for the model's needed longitudinal practice are briefly explained in the conclusion.

Keywords: Socio-technical systems, sustainability, appropriate technology, participatory design, design research

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Introduction

Even though this developmental framework is being presented and discussed as a Design model, it advocates that any such innovation practice cannot sustain without trans-disciplinary research partners/knowledge brokers related to the project at hand and furthermore positions any project intervention at the micro level of society, notwithstanding its connection to the meso- and macro-levels. Knowledge transfer is thereby centred in the Design practice as the essential conduit for scalability. In this paper, this centre space is acknowledged as the place for Participatory Action Research, occurring at the micro-level (tacit knowledge) within the model's ecology which is then connected the meso-level (embedded knowledge) as synergistic links of knowledge being brokered, organised and integrated through ongoing, iterative mapping and prototyping (Nogueira *et al.* 2019, p. 571). The model suggests that through this integration, the macro-level (explicit knowledge) can then be co-governed within an ecology. This aligns with Akubue's (2000, p. 39) sentiments of Participatory Design:

> [Being] able to allow for the development of products and concepts to evolve together with the users and ecology at large so that the result fits both with what the users want and what the system requires to thrive.

Research approach

Towards understanding Design's tangible influence, a pragmatic, normative paradigm was used to discuss this Design approach, the findings however, recommend trans-disciplinary cross-sectorial collaboration and further investigation from alternative paradigms and epistemological groundings. Towards these deeper understandings, Design Research is both empirical and imaginative (Johnson 2003, p. 39). Pragmatism can also go beyond the theory-practice divide, expressing a view of knowledge as an active process shaped through ongoing, contextual experimentation (Dalsgaard 2014). Similarly, "Design Research" represents research as a "kind of Design" instead of a "kind of research" (Faste & Faste *20*12, p. 4).

To oppose dominant technology applications (ordered from macro- to micro-levels), this model favours the micro-level as it possesses the essential tacit knowledge required to imagine appropriate solutions on the terms of micro-level individuals. These individuals are often unfavourably assumed as unable to articulate and prototype potential innovation opportunities in technical mediums within their context and/or seldom offered a platform to do so. The research question emerges as:

> How can cross-sectoral, trans-disciplinary, sustainable and innovative technology be manifested into resource scarce contexts by allowing the micro-level of society to govern such interventions as ongoing developments with the appropriate support from meso- and macro-levels of society?

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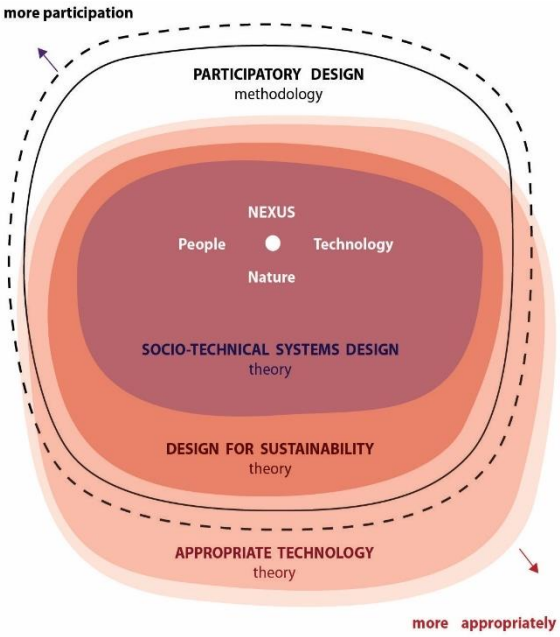

Figure 23: Hybrid theoretical framework (generated by author 2025)

Beyond this, the complex context of this research approach needed further ethical guidance. Participatory Design views participants as experts, acknowledging that Designers are not superior (IDEO HCD Toolkit 2015, p. 17). This "blurs" the Design role where, users often play an active role in Designing (Sanders 2002, p. 2). Stanford and Higgins (2023) offer the insight that Designers both extend and receive invitations to engage in projects, and the semantics of this interaction is key to the good nature of the project. If treated openly, this entails an oscillation of roles where Design can become an open tool for all to be guests, hosts, learners, thinkers, creators and visionaries (Stanford & Higgins 2023). Young (2008) refers to these different roles as shifting mental modes that drive the decision-making for aligning strategy with behaviour.

The Design is compromised when assumptions are made about roles and needs. Innovation opportunities are missed when essential tacit knowledge is excluded. Stanford and Higgins (2023) suggest actively acknowledging that people are good without intervention. By respecting the identity that people have or are yet to establish, their roles are honoured. Gently asking to co-create should involve a facilitation where all are equal guests to the learning process. It may seem intuitive to set the scene for participation, however openness to an emergent evolution asks Designers not to pre-programme a project process. Much can be done, though, to encompass participants' voices such as; referring to strong research and protecting the work from biases. A semi-structured approach to qualitative research (such as informal interviewing) opens a doorway to creating accessible processes and Designs. This model opposes early modes of Industrial Design that focused on dictating peoples' actions via a finalised idea, centralising technology within ecologies and nudging people further into mechanic modes of being (Ceschin & Gaziulusoy 2016, p. 143). Giving agency to the users allows for the much-needed power shift from dictation to creation. This asks Designers to approach innovation with soft Design builds, leading to more agile, 'hack-able' Designs, processes, systems or technologies.

Hybrid theoretical model

This developmental model suggests that the complex nexus of people, nature and technology in relation to Systems Innovation, requires a hybrid theoretical framework (Figure *1*). The combined

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strengths of the three chosen theories offset the limitations inherent in each one. The model pairs an overarching Participatory Design methodology with the theoretical goal of Appropriate Technology and is supported by the principles of Socio-Technical Systems Design (STSD), positioning the relationship between people and technology at the core. These general Design approaches are then reinforced by the conscious principals of Design for Sustainability, which highlights the importance of considering societies as ecologies, pulling nature into the centre as well. As a result, unsustainable 'progress' centric outcomes are blocked and redirected to focus on systematic process driven interventions, aiming to decentralise/distribute beneficiation within marginalised urban ecologies. Design for Sustainability also suggests a paradigm shift which questions the normative Design rehearsal that is still largely embedded in production industries, asking Designers to steer away from the resource exploitation pitfalls of our past, upon which so much technology relies. This positioning illustrates that there will always be space to participate more appropriately in the endeavour to amalgamate humans, technology and nature.

All three theories suggest using Design for thinking and rethinking at a systemic level to benefit the micro level on its own terms. The model is framed around the centre where humans and nature are ideally acknowledged as a symbiotic ecology integrated with technology. A challenge of engaging with the central theory of STSD, is that the systemic approach can be too "big picture" when trying to solve specific problems (Ceschin & Gaziulusoy 2016, p. 141). Participatory Design helps this by placing peoples' needs and experiences in focus, allowing micro, tacit knowledge to direct and ground a study through action within a specific context and creating a platform for development and open evaluation. STSD however, emphasises the relation to people more than nature. The model encapsulates it within Design for Sustainability to inspire resource-conscious Design that places ecology recovery in equal focus. The theory and practice of Design for Sustainability, however, has yet to reach a level of effectiveness proportionate to the world's escalating technological progress. The concept of truly sustainable innovation is strenuously evolving in its combat with the ever-changing landscape of the climactic impacts of the Industrial Revolutions. To attend to this crisis, Appropriate Technology innovation has been identified as a Design change agent that empowers ordinary civilians to consciously consider the possibilities within their resource context. Appropriate Technology's main bind, though, is that it is reliant on and constrained to the socio-technic context within which it is implemented. Consequently, resource-scarce contexts are deemed to only evolve to a point of low-tech applications. To transcend this constraint, STSD theory is leveraged by lodging integration of a study context into a multi-levelled (micro, meso and macro) urban system map. The outset of Participatory Action Research at the micro (individual) level is mapped in relation to the meso (organisational) and macro (social system) levels which reveals potential avenues of innovative research, knowledge brokering, resource streams and policy changing opportunities (Figure 2).

By centring the micro-level, Design practice gets orientated towards rich bio-diversities. It opposes the dominant precedent trajectory of Design's role in macro-oriented resource depletion for short-term gains in the hands of few. A pilot application example of this multi-levelled urban mapping revealed that in such complex contexts, a customised and coordinated effort is necessary, where the process is deliberated rather than the market saturation for sake of centralised profits (Abbas 2021, p. 57). These multiple viewpoints of stakeholders and role-players that are plotted in relation to one another, enable the many essential capitals of an ecology's ecosystem to be mapped to reveal engagement avenues towards potential healthy futures. Design practice is thus positioned as an open-motion continuum towards these possibilities (Abbas 2021, p. 56). The urgency for Designers to adapt their role in the world has been noted yet it is essential to include all relevant disciplines within a given praxis context. Honourable mentions at this stage of development include the sciences (social, natural,

environmental), the arts and the philosophies. Manzini (2014) reminds us that Design for social innovation is far from being mainstream but could hopefully be what Design of the 21st Century is. This hybrid developmental model aims to contribute to this existing gap.

Participatory methodology

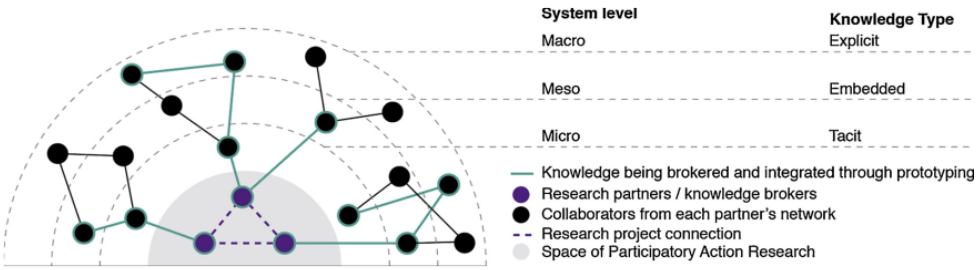

Figure 24: Participatory action research (PAR) framework (Nogueira *et al.* 2019, p. 570)

The three chosen theories all call for a deep understanding of a project's context ecosystem. Similarly, pragmatism urges for a systemic view of situations, acknowledging individuals as highly resourceful who, like Designers, organise and shape their circumstances by interacting with artefacts and systems (Dalsgaard 2014). The method of Participatory Technology Development has been advocated for resource-tight holdings as a way of increasing the likelihood that technology developments will be suitable (Bellon 2001, p. 7). Participant sampling is based on primary, secondary and tertiary relation within this frame of a given project, including all levels of an ecosystem, from operations to management. The broader system can be preliminarily mapped from initial research where role players are included as current and potential actors. The longitudinal nature of participation requires an evolutionary map of participants.

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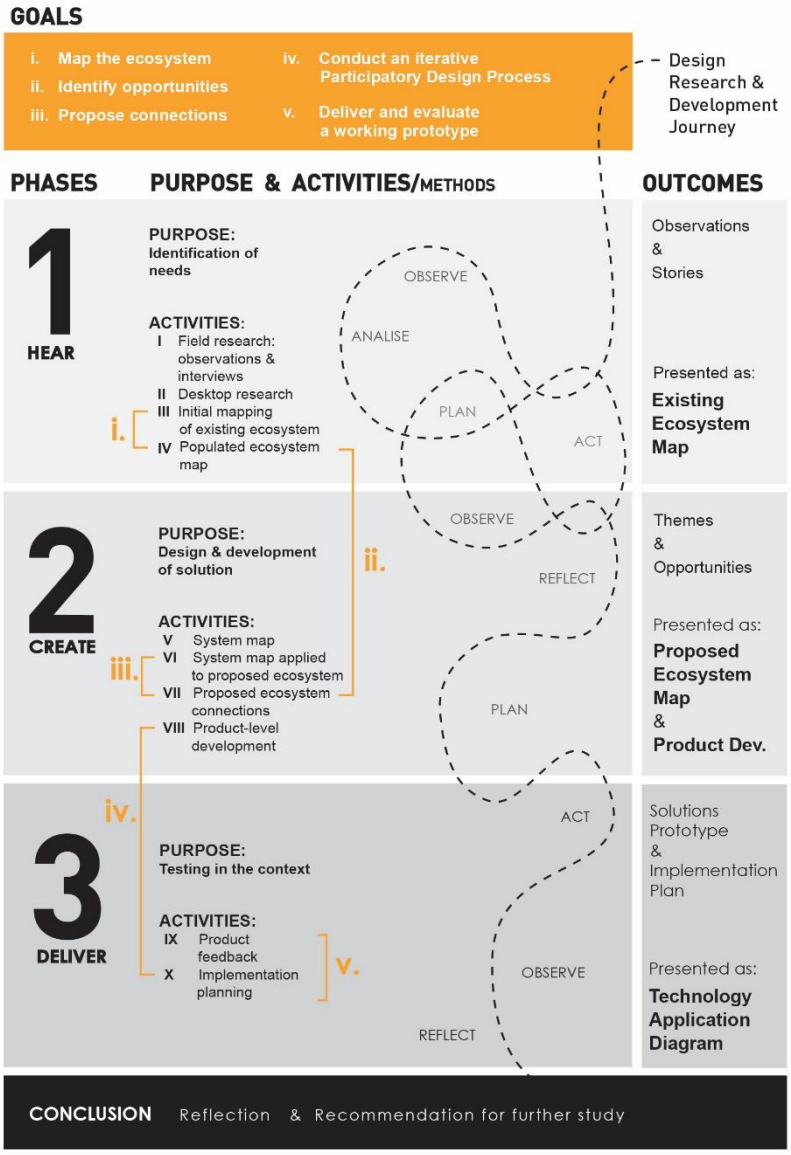

Figure 25: Study phases inspired by Ideo HCD with plotted goals (generated by author, Tofas 2024)

The IDEO HCD (Human Centred Design) stages inspired this model's engagement strategy, which constitutes a project in 3 phases; 'Hear', 'Create' and 'Deliver'. An example of this application is shown in *Figure 3*, depicting a journey potential through observation, analysis, planning, acting and reflecting and the outcomes, activities and purpose of each phase. This leads to an implementation plan to pilot and scale an initial socio-technic implementation into an ongoing project (Brown & Wyatt 2010, p. 35). The 'Hear' phase involves gathering observations and stories via mixed-methods data-gathering. The 'Create' phase sees the identification of opportunities and themes through interpretive and thematic analysis of the data gathered, which can then be plotted into a system map. Finally, the 'Deliver' phase synthesises the 'solution', embodied in a prototype artefact that is to be accompanied with a 'technology application diagram' that serves as an info-graphic mapping the future development possibilities of the initial prototype and prototypes alike. The 'technology application diagram' is Designed to serve the user by demystifying the make-up of the artefact. It should synthesise the data and resources mapped (micro-macro) that apply to the artefact at hand, encouraging the user to adapt/hack it for customised upgrade.

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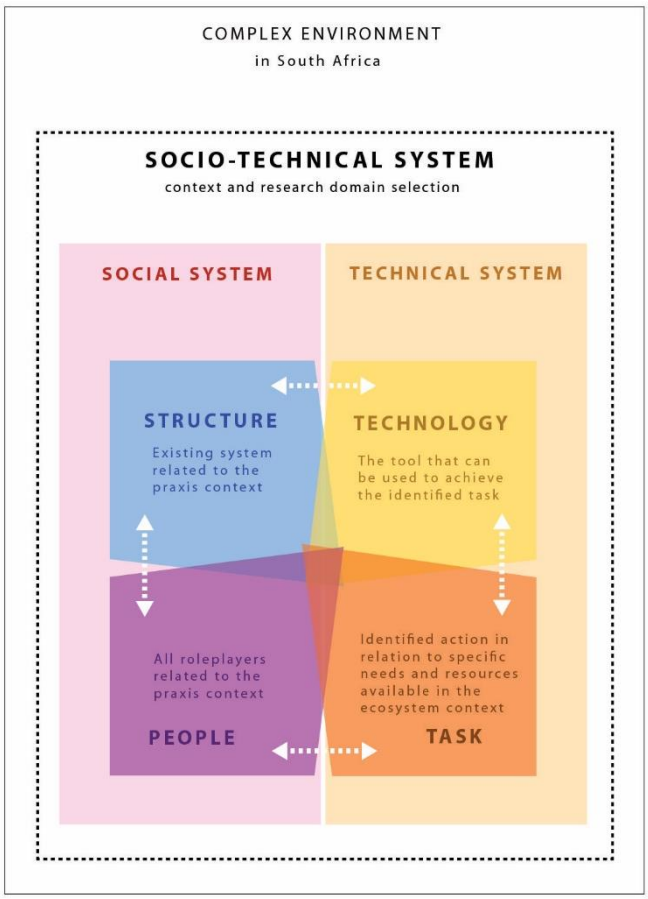

Figure 26: Synthesised socio-technical system model (inspired by Valdez & Brauner 2016; adapted by author 2025)

This process was Designed to help researchers, Designers and other participants make decisions together in the form of developmental diagrams, sketches, maps, mock-ups and prototypes (Pals & Kort 2008, p. 277). Additional conditions needed for Participatory Technology Development include; securing the willing participation of all participants, basing the practice on an appropriate diagnosis and site selection, framing Research Domains that support each other, insuring transparency at all stages, rendering required resources available to disseminate, dismantle, hack and reorganise the technology and ensuring the ongoing, long-term engagement needed for this approach (Conroy & Sutherland 2004, p. 1).

Socio-technical systems design

STSD theory has been used to Design adaptable systems for complex and changing social environments involving "culture, organisation, the context of use, usefulness, policies and regulations" (Ngowi & Mvungi 2018, p. 310). Within the complex socio-technical system of South Africa's small-scale (decentralised) producers, this theory together with participatory methods is suited for a systematic approach to co-innovation. If, as Feenderg (1999, p. 2) states, Design is recognised as an instrument to manifest the position of power held by people within a society, the Design process must be integrated by individuals adapting it to suit their ecosystem on their own terms. A Design intervention can then be considered truly democratic (Feenberg 1999, p. 206-208; Leavitt 1965). Leavitt's (1965) model acknowledged the interacting elements of a socio-technical system as the; structure, people/actors, task and technology. Valdez and Brauner (2016, p. 484)

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developed this further, positioning these system elements within a broader organised socio-technic sub-system and an even broader complex system (Figure 4). Philosopher of technology, Günter Rophol (1999) describes socio-technical innovation as "both social and technical phenomena, persons and machines, the technisation of society and the socialisation of technology". He links the act of invention to social change: "Every invention is an intervention, an intervention into nature and society. That is the reason why technical development is equivalent to social change" (Rophol 1999).

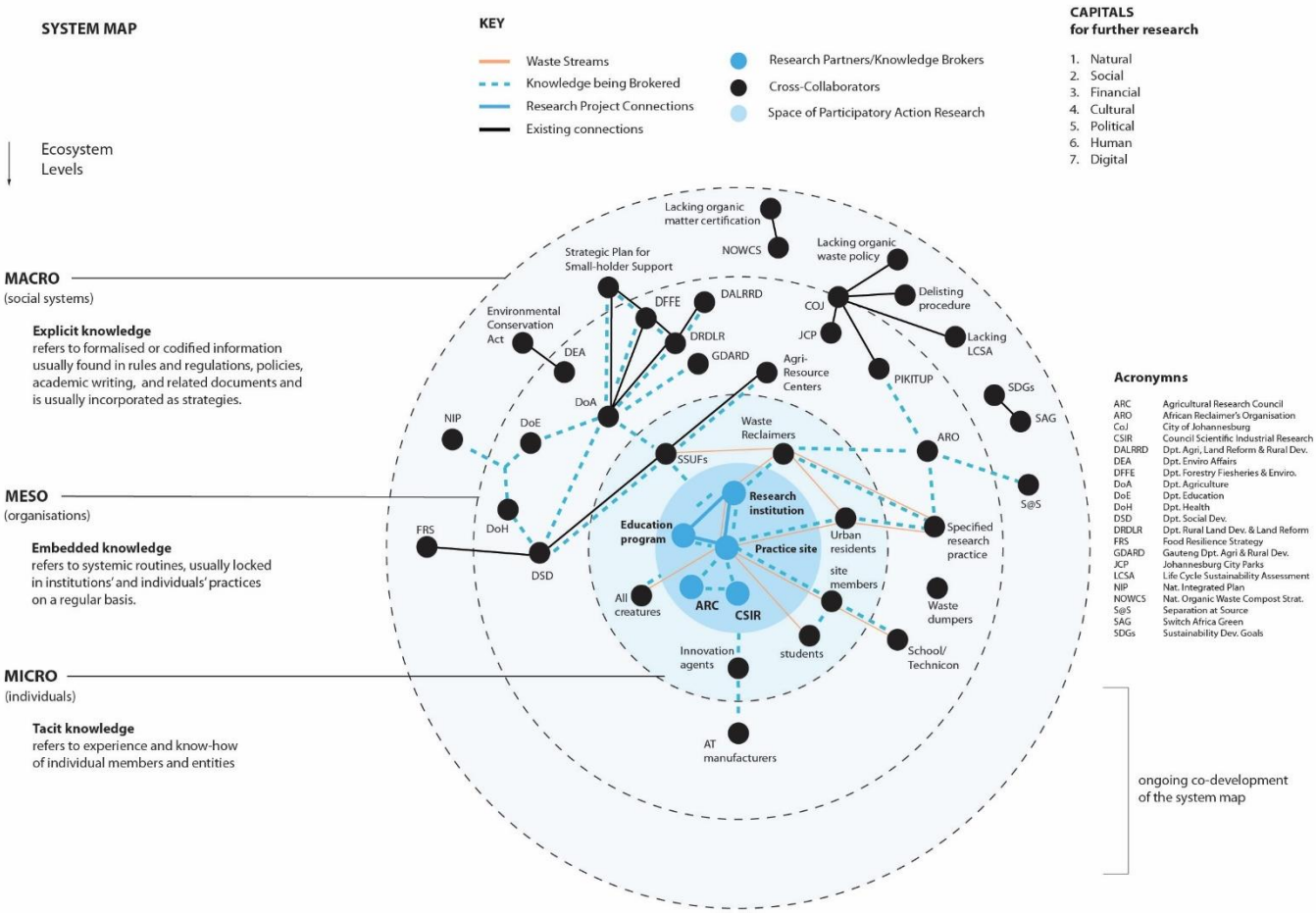

Figure 27: Example of PAR system map (inspired by Nogueira *et al.* 2019, generated by author for an ecosystem study related to appropriate organic waste management technology implementation at the University of Johannesburg's Centre for Ecological Intelligence; Tofas 2024, p. 102)

Frank Geel's (2004, p. 900) seminal article reveals the clear link between STSD and Systems Innovation where both approaches are interdisciplinary, holistic frameworks and innovation is an evolutionary process, as opposed to the history of innovation as a goal for reaching optimality. The notion of optimality yields static markers and thus cannot be applied to the process of innovation for system change (Edquist 2000, p. 285). The System Innovation approach rejects isolated development and promotes cross-collaborations with organisations, alliances, actors and consortia (micro- and meso-societal levels). Beyond this, Geels highlights the influence of institutional rules of engagement within a broader social system. Valdez and Braunder's model describe these as; regulations, laws, norms and technical standards (the macro-level of society). In acknowledging all systematic determinants,

Edquist (1997, p. 14) urges that evolving our technological systems thinking and practice with societies requires moving beyond STEM disciplines and business economics and connecting to other forms of knowledge in societies (Nogueira *et al. 20*19, p. 570).

Deeper research into the roots of the historical intensions of innovation were undertaken to understand how to apply STSD with reframed values for public interest (Tofas 2024). Except for very few organisations, a history of about 70 years has been very frustrating for STSD development. The concept was intended to enhance work systems in British coal mines (Trist & Bamforth 1951). It also has a therapeutic background of seeking a wider range of techniques to assist WWII-damaged soldiers return to civilian life by regaining their psychological health. In 1972, the application was focused on restructuring monotonous working life conditions by recognising that adaptable technology led to benefits on all levels of a system/organisation. The Council for the Quality of Working Life including members, mostly academics, throughout the world formally internationalised the STSD movement. The 1980s and 1990s saw the gradual fading of these initiatives as 'downsizing' flattened hierarchies and steered special knowledge into the hands of few. The goal of optimality controlled and coordinated work into tight, simple, repetitive routines resulting in few opportunities for human development and degrading individual potentials by intensifying faster, more streamlined, less interesting and more stressful work (Mumford 2006, p. 317; Stace 1995, p. 561). In this context, STSD approaches had no value (Mumford 2006, p. 331). Similarly, the digital age has perpetuated these operations into complex and open systems, created for 'progress' sake in the interests of stakes and stocks (Abbas 2021, p. 55). Typically, in urban spaces, most work happens at the edges, yet the benefits are mostly felt at the centre. Monopolies are enabled by such imbalances of power and knowledge is effectively fragmenting and removed from the micro-level (Michael 2017, p. 7). This setup blocks opportunities for meaningful collective action and resilience in social systems.

The less explored terrain of STSD asks for spaces of adaptive learning and freedom to create depending on individual notions of ingenuity. Incompletion and open-ended features are a key notion inherent in agile, healthy Design practice that creates spaces for people to play with ideas (Pasmore *et al. 20*18). Evolving conditions should be met with continual collaborative rethinking of structures and objectives without external supervision or hierarchies of control. Individuals can then be seen as complimentary to a technology, not subordinate to it (Mumford 2006, p. 317). This summary of STSD emphasises the urgency to address the needs of society, through embedding values by Design. The intersection of STSD and Public Interest Technology (PIT), positions innovation as a tool to reframe societal democracies (Abbas 2021, p. 55; Friedman 1996, p. 23) and asks Designers to understand what public interest is and the role technology plays in relation (Wheeler 2006). PIT discourages siloing and seeks the reconciliation of practice domains and public policy into trans-disciplinary knowledge and informed debate (Schneier 2019, p. 84).

Appropriate technology

Technology is recognised as a spectrum (of simple-to-complex) applications using different kinds of knowledge; natural, indigenous, chemical, physical, mechanical and computational. It can be found in the fabric of biological processes and thus exists before and without human intervention (Bobboi 2014, p. 54). Indigenous heritages of knowledge hold an accrual of technical knowledge that is often in alignment with specific natural contexts as these applications have emerged through long-term ecological integration. More academically recognised technologies are described to have scientific or engineering knowledge applied. All technological forms have functional purposes and intentions embedded within them, be it a binary code, genetic code, molecular or mechanic orientation (Bobboi 2014, p. 54).

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Given this plethora of potential applications, this paper's model is concerned with moving beyond the limited historical trend of technology being handed from 'developed', to 'developing' nations. "Technology can be and is [historically] configured in such a way as to reproduce the rule of the few over the many" (Feenberg 2004, p. 2). This restricted dynamic has resulted in exercising increased control and the occurrence of numerous technological mismatches in cases where basic developmental human needs remain unmet or in decay (Schumacher 1973; 2010, p. 189). If we return to the functional purpose and intention embedded within such industrial-scaled technologies, we find that they have been developed primarily for the monetary profit of few individuals. Mumford (2006, p. 317) has explained that this build tends to bypass user needs and control them. Andrew Feenberg (2004, p. 2), philosopher of technology, warns that without sensitivity to these baked-in prescriptions, technology can be a form of political control over a society. A sensitive response is needed from Designers towards understanding what is more appropriate for ecologies and asking whose risks are protected with a given technology and whose and what benefits are sought.

in 1962, Ernst Friedrick "Fritz" Schumacher, coined the concept of Appropriate Technology and later preferred to refer to it as 'intermediate technology' which alludes to finding an appropriate place on the low-high end spectrum of technology. Its purpose was to reform mismatches through accessible technology instead of imported technology (Schumacher 1973; 2010, p. 189). To do so, production methods must be catered for locally available manufacture and repair and use intuitive, relative processes. In 'Small is Beautiful: Economics as if people mattered', Schumacher argues that to realise substantial material growth for ordinary civilians, there needs to be a movement within manufacturing where smaller, more decentralised organisations are developed (Schumacher 2010, p. 144; Akubue 2000, p. 35). Technology mismatches are found in the small sector of SA with a lack of suitable equipment and training (Mhlongo 2023, p. 9). Mass-production approaches generally do not fit applications available locally to small-scale production contexts (Zelenika & Pearce 2011, p. 14). These are often imported technologies generated by fossil fuels and come with incurring environmental and monetary costs and are mostly complex mechatronic setups needing specialised imported diagnostic equipment (Weis 2010, p. 333).

The success of an Appropriate Technology intervention pivots on it is transparency. This requires demystifying the value impact of Design by engaging local community members and building a culture of open evaluation (Lasky 2013, p. 24-33). An artefact of Appropriate Technology is not definite within a living system, but open to evolution by its users. Embedded knowledge can then be disseminated directly through individuals (Mumford 2006, p. 321, 336). This leads to possible paths of intelligent institutions or alliances of knowledge transfer and enterprise development (Hazeltine & Bull 2003, p. 9). A more recent development of Appropriate Technology is Open-Source Appropriate Technology (OSAT). OSAT is a model of an open knowledge market (Pearce *et al. 20*12, p. 42). The Creative Commons is a widely used non-profit example of this knowledge sharing in the forms of historic images, scientific articles, digitized cultural artefacts and equipment, educational resources, music, 3D models, etc. Other topics or terms in resonance with Appropriate Technology include 'alt-tech', 'mid-tech', 'off-grid-tech' 'adaptive-tech', 'soft-tech', 'Design for the other 90 percent', 'frugal innovation' and 'light capital tech'.

A limit of Appropriate Technology can be that it relies on local resources. In resource scarce contexts, this limits technological development where Appropriate Technology artefacts have often been referred to as "poor" or inferior technology. There is still much tension in the debate about technology's appropriate application. High-end cyber technology is criticised for its subordination of users juxtapose discussions that such high-end advancements are imperative for ingenious transformation in the emerging sector. Tacit knowledge on the micro-level is being mined and

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undermined instead of catered for while advanced technologies are being cornered off. This paradox is helped by the theory of STSD, where connecting the micro-level of society to the meso- and macro-levels provides pathways out of labour-driven technology into adaptable futures on the terms of micro-level individuals. The implementational intention of this model champions 'hack-able' and off-grid technology and transfers control to users within an operational framework that promotes productivity driven by available resources and cross-sectorial support.

Design for sustainability

Historically, sustainability work has sought to redress the misalignment of human activity and the natural world towards regenerating Earth from the mass-scale industrial extraction of resources. It initially orbited addressing the foreseeable dangers to humanity with a global emphasis on the environment, as society's future depends on its resources (Ceschin 2016, p. 118; WCED 1987, p. 43). This report (The Brundtland Report, commissioned by the UN) instructed to; firstly, address the basic needs of the planet's poorest and secondly, address the immense pressure that mass social organisation and technological advancements exert onto the Earth's ability to regenerate itself. Terms such as "green Design", "eco-Design", or "environmental Design" are often used interchangeably with "Design for Sustainability", yet, to date, there is no universal consensus for sustainable Design development practices (Chatty *et al. 20*22, p. 2). In the 80s, the World Conservation Strategy was formed to reconcile economic and environmental needs. It was, however, unsuccessful in translating environmental needs into coordinated economic policies, a functioning mandate or substantial integrated practice (Majah-Leah 2015, Pearce *et al.* 1989). A longitudinal study of sustainability efforts reveals a current global position of both hope and despair (Tofas 2024). Despite this, sustainability's academic findings have evolved dramatically, based on several empirical case studies. "In hindsight, we can see the [needed] shift from progress centric to process centric approaches" (Hughes *et al. 20*13, p. 9).

Unfortunately, many countries clutch on to the post-war structure of industrial development. Sustainable operations are blocked by mass corporations still using these systems. Here, 'Sustainable Design' is only considered from the point of minimising costs to increasing profits. These include many nations that are the most 'developed' in terms of socio-economic pointers and ironically, with the highest SDG scores (Hickel 2020). Currently, there are only eight countries considered as carbon neutral; Gabon, Bhutan, Suriname, Panama, Madagascar, Niue, Guyana and Comoros. This is only due to their untouched green expanses. There is a gap in the SDG indexes where sustainability as a metric, needs to be met on all sides of the wheel. The Human Development Index for example, uses indicators of education, life expectancy and income per capita, yet is not an equal indicator of success. Industry practitioners fail to use Sustainable Design Methods and Tools (SDMTs) systematically but rather as ad hoc parts like they do with traditional Design techniques (Chatty *et al. 20*22, p. 2).

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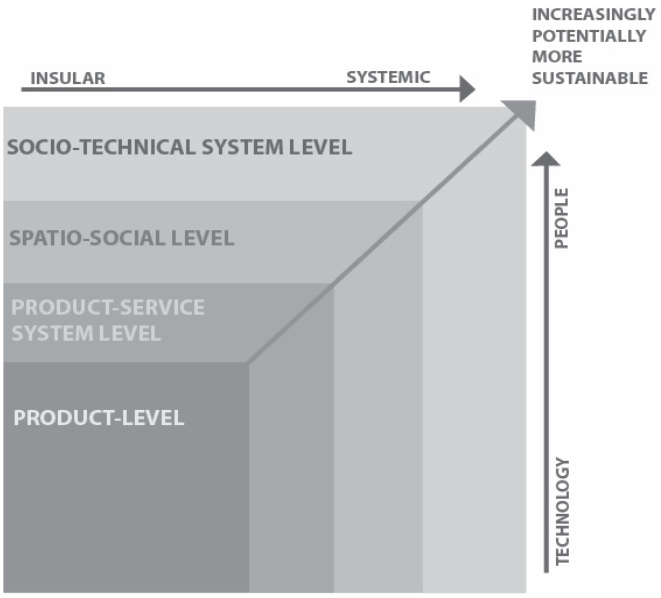

Figure 28: Design for sustainability evolutionary framework (Ceschin & Gaziulusoy 2016; adapted by author; Tofas 2024, p. 143)

This section reveals ways that sustainability concepts can hack into smaller-scale, context specific operations to bypass the largely failed umbrella approach. Design is identified as both having been used poorly to germinate the Industrial Revolution and as a primary change agent for innovation for future urban systems (Ceschin & Gaziulusoy 2016, p. 119). Case study research indicates that to meet the complexity of this tension, sustainability should be applied to context-specific indicators (Faber *et al. 20*05, p. 22). Sustainable practice has moved from the insular product-level (narrow, technical outputs) to a socio-technical system level (Figure 6) (Ceschin & Gaziulusoy 2016, p. 144; El-Halwagi 2012, p. 1). This model embraces regeneration using the Circular Economy concept where Design informs process and material selection and fosters closed-loop material flows (Gopal 2023, p. 2). The selection of strategies should be informed by the stages of the development process; 'Discover', 'Define', 'Develop', 'Evolve', 'Realise', and 'Support' (Chatty *et al. 20*22, p. 2; Ramani *et al. 20*10, p. 132). The initial phases are usually full of uncertainties, yet critical decisions are required regarding product architecture, manufacturing processes and materials selection (Chatty *et al. 20*22, p. 2). The Life Cycle Assessment is a projection that can assist by relating iterative product and system Design to source identification, extraction/processing of raw/used materials, manufacturing, distribution, uses, disposal and after-life (Amasuomo & Baird 2016, p. 90).

Sustainability urgently needs to account for other forms of knowledge in the pursuit of moving beyond anthropocentric needs and reconsidering the extent of biodiversity (terrestrial and aquatic) decline holistically (Ceschin & Gaziulusoy 2016, p. 119). This radical change is needed in the form of appropriate innovation as well as social, cultural, and behavioural changes across societal scales (Ceschin & Gaziulusoy 2016, p. 119). The various approaches and tools developed within the theory of Design for Sustainability provide more specific strategies for this research process; Design for System Innovation (using a Life Cycle Assessment to mimic regenerative ecosystems of nature) Design for Sustainable Behaviour (moving people to the centre of the process) (Sherwin 2006, p. 26), Design for the Base of the Pyramid (activating roles for users to act as co-creators) and Design for Sustainable Social Innovation (facilitation of replication and scaling up) (Ceschin & Gaziulusoy 2016, p. 126).

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Conclusion

The research indicates an urgent need to move Design Research, practice and education towards a trans-disciplinary cross-sectorial collaborative process. This can assist projects to go beyond the normative paradigm and offer profound 'new' knowledge of the ecologies that Design aspires to function within. The model offers a means to sustainable socio-technical project continuums, by stirring micro-levelled knowledge transfer. It relies on open co-practice, in favour of softer Design approaches that allow transformations as opposed to conformations.

The research is based off longitudinal studies of intersecting Design theories that indicate empirically based rescue paths out of Earth's projected socio-economic and environmental catastrophes. This intersection of Designing for innovation asks for ongoing praxis on adaptable technology cases that are generated from this or similar theoretical models. To do this, there is a need for more open-source micro-macro-levelled maps of existing fragments of Circular Economic practices in South Africa that can support decentralised, diversified production practices through more synergistic links. This reframing of overlooked resource capitals that Nogueira *et al.* (2019) highlight is the 'new' knowledge required for heathier, sustainable socio-technical continuums. The eventual depth of collaborative engagements over these maps would allow ways for societal systems to organise their own technological domains on their own terms and form the much-needed resource conscious solidarity that is lacking globally. The theoretical solutions and pilot example for Design research and practice application proposed in this paper should transfer to educational curricula and industry training incorporation. Collaboration to further define these questions would be novel.

Recommended applications of this model within the South African and global problem-scape point towards resource reclamation/recovery of energy, water and waste. This is an urgent topic cluster, recognised by the South African state as needing innovative intervention (DFFE 2020, p. 4). These renewable, regenerative processes are popular global topics, however, there is a lack of ingenious development around more intermediate, appropriate and accessible technologies. In summary, this model combines Design Research practices, theories and careful Participatory Design to channel co-creative innovation towards a better world wherein the relationships between nature, humans and technology are more consciously acknowledged.

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