Knowledge Creation in a Participatory Design Context: The use of Empathetic Participatory Design

Stephen Kyakulumbye, Shaun Pather and Mmaki Jantjies
University of the Western Cape, Cape Town, South Africa
3759606@myuwc.ac.za
spather@uwc.ac.za
mjantjies@uwc.ac.za

Abstract: The growth and penetration of Internet across developing countries has led to availability of a plethora of ICT applications. Quite often, potential users of these applications hold varying perceptions, both negative and positive, in respect of potential usefulness. This in turn, results into variations in adoption outcomes. The extant literature posits that 80% of user perceptions are negative while only 20% of their perceptions towards available ICT application are positive. The negative perceptions inevitably results in low adoption or at times even non-adoption of applications, which then remain under or un-utilized. This paper reports on a participatory action research study, which explores how ICT application adoption may be enhanced through 'empathetic participatory design' as a method for creating knowledge that may have meaningful application utility. This is achieved through user behavioural simulation. The main mode of data collection and analysis was the repertory grid technique used to elicit constructs from simulated prototyped elements of a selection of applications. In this paper, the knowledge creation process involves the use of design scenarios and use-cases from the typical users' point of view during co-problem discovery and scoping in respect of problems identified by the user community. The findings of this paper reveal that a co-design approach results in reflective experiences, that create a hybridity of knowledge which is both tacit and explicit, reciprocating each other to enrich the design outcomes of the applications. We argue that knowledge is not only a belief of knowing and thinking but rather has the ability to be transformed into real action. The paper posits that tacit and explicit forms of knowledge are inextricably linked and that knowledge is created and expanded through social interaction between tacit knowledge and explicit knowledge using modes and methods of 'knowledge conversion'.

Keywords: Co-design, Empathetic participatory design, repertory grid technique, prototyping, situation awareness, tacit knowledge, explicit knowledge, ICT development

1. Introduction

The growth and penetration of Internet across developing countries has led to availability of a plethora of ICT applications. Quite often, potential users of these applications hold varying perceptions, both negative and positive, in respect of potential usefulness. As a consequence, this results into variations in adoption levels (Sin Tan, 2009). Based on the Pareto rule, it is claimed that 80% of user perceptions are negative while only 20% of their perceptions towards available ICT application are positive (Oztekin, 2011; Oztekin. et. al., 2013). When users hold negative perceptions towards available ICT applications, then low adoption or non-adoption prevails and such systems remain under or un-utilized (Verdegem and Verhoest, 2009; Kim, Chan and Gupta, 2007). Such a situation, in the case of e-Government to Citizen applications, often leads to sunk costs and loss of public fiscus. In considering the extant literature and practice, a question arises in terms of '*How can these negative perceptions be mitigated in order to attain effective user adoption and how can such perceptions be converted into knowledge during a participatory design process?*' This is the primary question which frames the research reported in this paper.

In the context of the research question, the reciprocation of knowledge results from developers asking users to critique application prototypes when they lack domain knowledge to implement an element of functionality rather than implementing their best guesses (Fischer and Ostwald, 2005). Prior to a participatory design process with potential users, the empathetic design process helps developers to create tangible expressions of ideas through concrete action. As a consequence, developers learn faster by failing early (and often) before getting exposed to their users (Coughlan, Suri, and Canales, 2007). These authors further observe that when application elements are made tangible early in the design process, then small, low-impact failures occur early, resulting in faster learning and thereby facilitating the exploration of new behaviors on the part of developers (*ibid*).

Reference this paper: Kyakulumbye, S., Pather, S., and Jantjies, M., 2019. Knowledge Creation in a Participatory Design Context: The use of Empathetic Participatory Design. *The Electronic Journal of Knowledge Management,* 17(1), pp. 49-65, available online at www.ejkm.com

The context for the ICT application design process reported in this paper is that of a local community setting in Uganda (Mukono District) in which typical community problems were explored. We use design scenarios from the typical users point of view during co-problem discovery and scoping in respect of the following co-discovered community problems: fire reporting, reporting kidnapping, neighborhood watch (business and personal) and bus transport applications. The paper is guided by the following questions in respect of the empathetic participatory design process:

1. What are the underlying constructs, from an empathy perspective, of designers in respect of application designed interfaces?
2. How can these constructs be categorized into the cognitive criteria of perception, comprehension and projection of users?
3. What key lessons can be reflected on from this empathetic participatory design process?

The next section reviews the literature in order to find a juxtaposition for empathetic participatory design constructs and how such constructs reciprocate into knowledge creation and enrichment.

2. Literature review

2.1 The notion of knowledge creation

Critical to understanding knowledge creation is the notion that knowledge resides within and is created by individuals (Nonaka and Takeuchi, 1995). The know-how and information that individuals gain over time forms their knowledge stocks (Soo, et. al, 2002). It is the current knowledge stocks which shapes the scope and direction of the search for new knowledge, implying that knowledge creation is a path-dependent process (McFadyen and Cannella Jr, 2004). This further implies that through participatory design, newly acquired inputs are integrated with existing knowledge stocks (Moraine, et. al, 2014) hence a reciprocation of tacit and explicit knowledge. It is observed that whereas tacit knowledge essentially represents “know how” (the subjective knowledge), explicit knowledge is “knowing about” (objective knowledge) (Nonaka and Takeuchi, 1995). Through participatory working, interpersonal exchange networks are important to scientific discovery both because knowledge is combined and shared with network members and because it is through networks that any research findings become "certified knowledge" (McFadyen and Cannella Jr, 2004; HK, et. al, 1999).

2.2 Participatory design

Davis (1993), in his research made a conclusion that there is a need for mechanisms by which design choices influence user acceptance within applied contexts. This proposition still has merit today and is the underlying premise of participatory design approaches. The community informatics literature reveals that with the design of applications, projects and activities within a community informatics framework that would be most supportive of *effective use* for grassroots communities, would be participatory design (Gurstein, 2003). Participatory design is a well cited strategy (e.g. Qureshil, Kamal and Wolcott, 2009; Wyche, 2015) and several fruits have been documented to date in respect of its application. It is a methodological approach that recognizes that ideas develop slowly over time, and can help discover confounding demi-regularities (Lawson, 1997) called contextual factors. It could also mitigate pre-usage beliefs and attitudinal expectations of users and helps to clearly understand negative generative mechanisms that could affect technology adoption (Van Aken, 2005; Andriessen, 2006; Jagosh, *et* al 2012). However, a key participatory design principle is ‘*empathy*’ hence this paper’s notion of ‘*empathetic participatory design*.’

2.3 Empathetic participatory design and knowledge creation

Prior to embarking on community participatory design processes, design teams need to engage in a detailed preparatory exercise by examining the potential user demographics, context and user situation through a process of empathetic participatory design (Kyakulumbye, Pather and Jantjies, 2018) or behavioural simulation (Morecroft, 1985; Staunstrup and Wolf, 2013). It is in this respect, that this paper focuses on the process of ICT application design and how the co-design team members bring forth their tacit and explicit design knowledge to enrich the design process and outcome before and during the typical user experiencing design phase. The adaptation of this approach of ICT application design which we term as ‘*empathetic participatory design*’ is drawn from several studies, including Lindsay et al (2012), Kouprie and Visser (2009), Hawley (2007) and Sanders (2003). The term empathetic user experience design is rooted in all of the latter studies. In our instance, the term ‘*empathetic’* highlights the importance of the design team to better understand a prospective user audience by living through common experiences or facing the same challenges related to usability as users may face. It is participatory in nature where the co-design team members walk through and rehearse the design methods prior to real design in a community setting. Empathetic participatory design enables the design team to make appropriate choices for users (Kouprie and Visser, 2009; Petersen, 2017). It has its roots in design processes which evolved when it was found that understanding user responses through questionnaires was not enough to develop successful artefacts (Sanders, 2003).

Participatory design acknowledges accountability of design to the lives of those who will be affected by the design process and its outcomes (Norman, 1988; Norman, 1999; Stolterman, 2008). The design team undertaking empathetic participatory design will have reflective experiences, resulting into a hybridity of knowledge. Such knowledge hybridity (tacit and explicit) leads to new diverse knowledges into design insights and plans for action (Muller and Druin, 2010).

2.4 Tacit and explicit knowledge

Both tacit and explicit knowledge types have been debated in the extant literature. Fundamentally, Cook and Brown (1999: 385) believe that "tacit knowledge cannot be turned into explicit knowledge, nor can explicit knowledge be turned into tacit". However, this paper argues that the two forms of knowledge may be reciprocal during the process of participatory design. The paper thus lends support to Wynn and Williams (2012) who argue that the generation of new knowledge is the result of "... *our interaction with the world*," because the world and entities that constitute reality exist 'out there' independent of our human knowledge. Knowledge is not only a belief of knowing and thinking but rather an ability to transform it into real action. We therefore argue that tacit and explicit forms of knowledge are inextricably linked and that knowledge is created and expanded through social interaction between tacit knowledge and explicit knowledge using modes of 'knowledge conversion' (Nonaka and Takeuchi, 1995).

2.5 Theoretical underpinning of the knowledge creation process

From a knowledge creation perspective, this paper focuses on the use of Personal Constructs Theory, and Repertory Grids (Kelly , 1955) mapped onto Endsley's situation awareness theory (Endsley 1995, 1997, 2000). The knowledge creation process is revealed through context mechanism outcome realist evaluation lens (Pawson and Tilley, 1997; Pawson, 2013; Jagosh, *et al* 2012) to unveil real and empathetic user knowledge.

2.5.1 Personal Constructs Theory (PCT) and the Repertory Grid Method

Repertory Grid is a data extraction and analysis technique rooted in Personal Construct Theory, developed by George Kelly in the 1950s (Wright and McCarthy, 2004). Repertory comes from the word repertoire, which refers to a participant's wealth of constructs, and grid refers to data extraction and analysis procedure (Hawley, 2007). The central theme of Personal Constructs Theory is that people organize their experiences that form their knowledge about the world into conceptual classifications (Hawley, 2007; Alexander, *et al.* 2010). These classifications can be differentiated and described using attributes of those classifications called constructs (Kelly, 1955; Wright and McCarthy, 2004). These constructs are revealed to manifest themselves as polar opposites on a scale, so we can be able to organize the elements of our world (Kelly, 1955). Kelly's approximation of events and constructs is that there is a real world of events beyond our comprehension, one that would exist even if humankind had never graced the surface of the earth (Butt, 2004).

Kelly's personal constructs theory (Kelly, 1955) and its cognitive mapping tool-the repertory grid (RepGrid) have been applied during the design and deployment of new information systems in a participatory manner. These include Hunter and Beck (2000) who conducted a cross-cultural study of Information Systems; Wessler and Ortlieb (2002) who undertook a user centered approach to measure a Website's Appeal; Tan and Hunter (2002) who measured cognition in information systems; and Napier, Keil and Tan (2009) who investigated IT project managers' construction of successful project management practice. The personal constructs theory and its repertory grid interview as developed by Kelly (Kelly, 1955), attempts to minimize the constructs bias of the interviewer (Wright and McCarthy, 2004). It also helps to generate constructs that are relevant to a given situation and context.

2.5.2 Situation awareness theory

Situational Awareness theory was advanced by Endsley (1995). It incorporates almost all variables involved in a comprehensive theory of human behaviour and human information processing, with particular attention to cognitive elements (Bedny and Meister, 1999; Bedny and Karwowski, 2003). The model is underpinned by three major cognitive processes which humans undergo during any information processing initiative:

- **Perception** is an attention-based selection of task requirements. It includes affordance (which implies how an application should be used), consistency, familiarity, recognisability, visibility, and benefits expectations (Rosli, 2015).
- **Comprehension** is an understanding of perceived information about a particular situation. It includes learnability, association, generalization, informative, ease of use (Preece, Rogers and Sharp, 2015).
- **Projection** includes feedback, user centeredness, support, user confidence, meaningfulness, prediction, pop up messages, signal displays and error detection functions among others (Rosli, et. al, 2012; Rossi and Rosli, 2015; Rosli, 2015).

Several other authors such as Lee and See (2004), Burns, et. al (2008) and Nardi (1996) have used this model for the design of systems and interfaces, thereby creating context based knowledge. For knowledge creation and reciprocation process, personal constructs theory and repertory grid technique helps to generate descriptive constructs that are grouped using the situation awareness theory human information processing model, all analyzed through the context mechanism outcome configuration evaluation lens (Pawson and Tilley, 1997; de Souza, 2013).

2.5.3 Context Mechanism Outcome Configuration (CMOc)

The co-design reported in this paper, is situated within a specific context. CMOc is a heuristic used to generate causative explanations pertaining to data with interest in a particular program as a whole or on certain program aspects (Jagosh, *et al,* 2012). A CMOc as related to this study concerns design teams' and citizens' experiences of socio-economic challenges for which ICT applications can be considered as a way to offer mitigating measures (*Context*). However there is evidently low adoption and usability among the marginalized communities (*Outcome*). The reasons for such low adoption are always under debate. Some have attributed it to users' and citizens' lack of knowledge and skill to put designed ICT applications into use and others due to low or inadequate involvement motivation (*Mechanisms*). Such mechanisms can be observed but at most times are hidden (Pawson and Tilley, 1997). A central tenet of such artefact evaluation is to answer questions by theoretically and practically developing and testing the evolving prototypes within a given context. It is postulated that *Context + Mechanism = Outcome* hence the acronym CMOc (Pawson, 2013; Pawson and Tilley, 1997). We argue that empathetic participatory design as a *mechanism* within a given *context* can stimulate an *outcome* of effective ICT application use sooner or later. However, there is a likelihood that based on Personal Constructs Theory, users develop bi-polar knowledge constructs when subjected to new technology.

2.6 Applying Personal Constructs Theory, Situation Awareness Theory and Context Mechanisms Outcome configuration lens to inform the co-design process

Context determines the user-designer expectations and this shapes the application requirements. All design team members contribute knowledge to the design activity in a reciprocal manner. Knowledge can be tacit or explicit. The activities introduced during the design process can influence the confirmation and disconfirmation of any possible inconsistencies that may affect application usage in the long run. RepGrids from Personal Constructs Theory can influence the design knowledge embedded into the design space. However, the naming of the constructs based on design and user evaluation is premised on the situation awareness human information processing model within a given context. As reviewed from literature, participatory design is a mechanism to reveal those constructs and later generate desirable outcomes (Context Mechanism Outcome). The results from effective participatory design are the desired outcome which is both decision and action. Decision may be an intention to use the designed application while action can manifest itself into adoption, actual use, and continued use. Empathetic participatory design influences the resultant constructs through a confirmation or disconfirmation process resulting into knowledge creation and reciprocation.

3. Methodology

3.1 Iterative Co-Design Research Model (ICoDeRe Model)

This paper employed a multi-methodological participatory action research process design approach using design science research methods and paradigms. Data was collected through observations, role-plays and repertory grids methods. The empathetic participatory design unit of analysis were third year Business Computing university students from Uganda. Participatory designer teams may be assembled from a group of community-dwelling adult citizens or students in university research labs (Ellis and Kurniawan, 2000). This study sought to co-design with students in a university setting. Druin (2002, 2010) describes four possible roles of students during participatory design process:

- As a user (who can be observed or assessed)
- As a tester (who is also asked for comments)
- As an informant (who offers feedback and input)
- As a design partner (considered as equal stakeholder in the design process)

However, while working with students as design partners, it is stressed that mature adult designers with highly formalized knowledge and experiential tacit knowledge should be gatekeepers to the design processes (Bovill and Bulley, 2011; Bovill, Bulley and Morss, 2011).

The overall design framework, which we term Iterative Co-Design Research Model (IcoDeRe Model) is presented in Figure 1. This framework guided the study process:

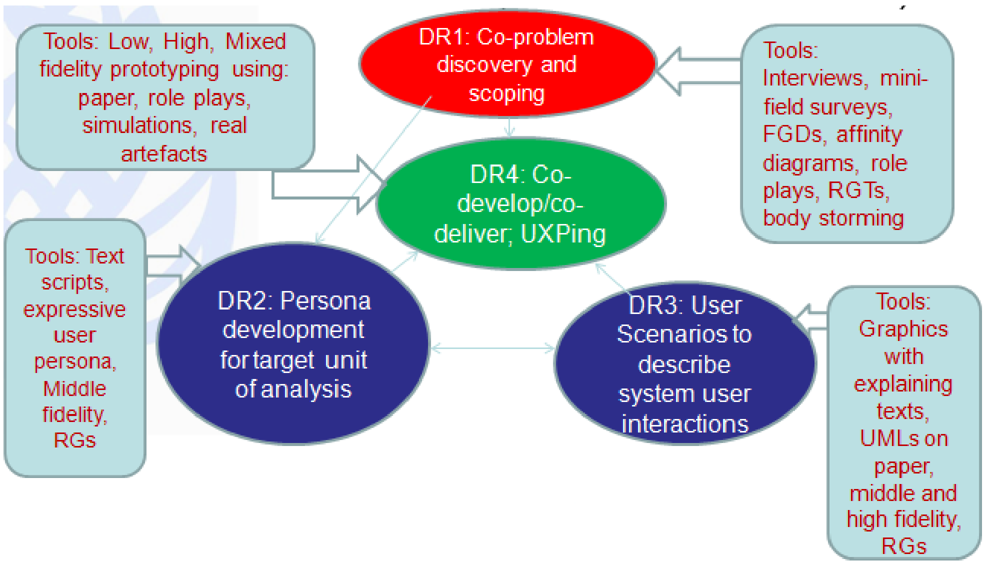


Figure 1: Iterative Co-Design Research Model (IcoDeRe Model)

3.2 Applying the Iterative Co-Design Research Model

From the above model, phases DR1 and DR4, involved community wide surveys, while working with potential user representatives from Small and Medium Enterprises. The latter two phases is not in the scope of this paper. This paper reports on the results of the iterative phases reflected in DR2, DR3 and DR4, which formed the empathetic participatory design processes. Furthermore, whereas a repertoire of methods and tools can be prepared for use during participatory design process, the results reported in this paper are for those methods and tools that were feasible to address the highlighted research questions. Briefly below is an overview of the design processes (DR2, DR3) and a high level preparatory phase for undertaking DR4.

3.2.1 Design Research 2: Persona development

Persona is described as one or several fictitious characters that can represent the majority of potential users of a system with conventional user demands (Thimbley, 1998; van and van Beurden, 2014). Personas help to describe the whereabouts, demographics, problems, beliefs and attitudes of intended users. In this study, role plays were used to determine the persona graphics with descriptive texts which were used to communicate a much clearer image, leaving much less to the imagination and thus creating a better common understanding as to who the target people are (See Figure 2).

Figure 2: Application user persona

3.2.2 Design Research 3: Use Scenarios and user cases

During this phase, scenarios were used to describe what the intended users want to achieve and how realise the objective by describing a specific system-user-interaction. These visualizations of user-product-interactions were continuously incorporated in the application design. The main use scenarios were to assess the actual user needs or desires. Figure 3 represents one of the use cases.

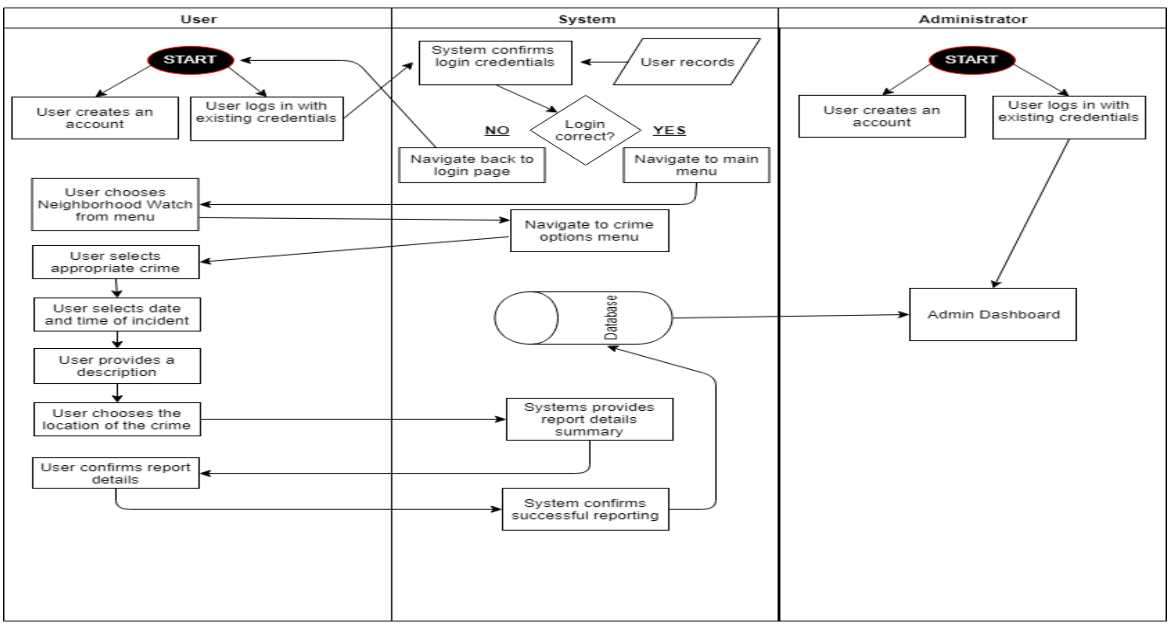


Figure 3: Use case for incident reporting

The role plays were used to refine use scenarios with explanatory text (see italicized text below), and use cases below as examples.

Use scenario

A user wants to report a fire outbreak in using the ReportIt mobile application. S/he logs onto the app by entering login details (email and password). He/she is an existing user of the application, so she does not have to sign-up as a new user. The system must now check the correctness of the user's login details. If the login details are correct it will take the user to the menu page showing various service *options where Fire is the main option to be reported. The user will then click on the Fire option to report it. User will choose the date, time, geographical location, description or record a voice note and then click confirm if information is correct. User will then receive a confirmation message if the report has been successfully submitted.*

3.2.3 Design Research 4: User experiencing phase

This phase is the gist of this paper. The experiencing phase brings together all other phases in order to communicate the research data, personas and scenarios. This occurred the forms of low fidelity using paper prototypes, middle fidelity and high fidelity prototyping. The results of the three level prototyping simulations were undertaken using a prototyping tool *JustInMind* (see https://www.justinmind.com). Throughout the empathetic participatory design process, knowledge creation and reciprocation was undertaken through abductive and retroduction analysis. However, the main research methodology for this paper was the use of repertory grid interview methods and tools, using paper and Justinmind low fidelity and high fidelity prototypes respectively.

3.3 Prototype development and evaluation

Prototype evaluation is essential to seek comments or ideas in improving the final outcome of the system (Rosli, 2015). It helps to move through diverse design ideas until the idea that meets user requirements has been identified. From the iterative Co-Design Research Model (ICoDeRe Model) in Figure 1, this paper reports on data generated from the prototypes developed during phases DR2-DR4. The developed prototypes involved graphical representation of the four systems designs. The four group prototypes are:

- **Find me app**: This an application intended to be used by a victim of kidnap to send a signalling to the authority or government security agencies like police for any emergency response
- **Quick App**: This is a fire reporting application just in case of fire outbreak within school and institution dormitories to offer real time response by responsible government agencies.
- **ReportIt App**: Is a neighbourhood home or business (SMEs) watch for any crime, theft or similar negative incidence to communities
- **U-bus**: This is an application for booking a bus as public transport in a constrained environment where transport is not easily accessible.

The prototype evaluation process that resulted into knowledge creation is based on the Repertory Grid technique.

3.4 Repertory Grid Technique and Process of Construction

A repertory grid (RepGrid) involves a number of participants who are knowledgeable about the topic being explored as well as the researcher (Alexander, et al 2010). It involves agreement on a topic; the identification or provision of a series of cases, examples, or, in Kelly's terminology, "Elements". In this study elements refer to applications which are being prototyped and the use of an interview in which a systematic comparison of elements enables the respondent to identify "Constructs" (Kelly, 1955). Constructs are ways a participant has of making sense of, or construing, the elements (prototypes). Constructs are frequently expressions of intuitions, "gut feelings," and perceptions, comprehension and projections which the individual uses as a guide to action, without necessarily having verbalized them explicitly prior to the interview (Björklund, 2008; Nehme, et al 2006; Endsley, 1997; Mezirow, 1993). They investigate attitudes and beliefs, concepts, assumptions, self-insight or reflection, understanding and cognition (Hunter and Beck, 2000). In using the RepGrid technique, a large sample is not required to reach a required level of redundancy and 15 to 25 participants can be sufficient (Tan and Hunter, 2002). Easterby-Smith (1980) recommends that since RepRid requires attention to details, small sample sizes of approximately 15 to 25 can yield a generalizable set of constructs. The constructs are bi-polar with extreme positives and negatives. The construction of the Repertory Grids was undertaken in the following four (4) phases:

3.4.1 Phase 1: Selection

In this study, co-design team members, herein referred to as participants, generated four prototype pool elements: a) Find me app. b) Quick App c) ReportIt App d) U-bus. During each session the team members were asked to draw up the grid using the initial prototype set. Table 1 is an example of a grid.

Table 1: Repertory Grid Template

Elements	Quick App	ReportIt App	Ubus App	FindMe App	
Constructs here (Bi-polar)	Rating	Rating	Rating	Rating	**Opposites of the constructs (Bi-polar)**
	Rating	Rating	Rating	Rating	
	Rating	Rating	Rating	Rating	
	Rating	Rating	Rating	Rating	
	Rating	Rating	Rating	Rating	
	Rating	Rating	Rating	Rating	

Rating scale 1-5 (1-least rated and 5-Most rated)

Each participant worked independently with the selected set of four prototypes which were listed on participants' sheets. The constructs can be in form of descriptors also called descriptor list. A descriptor list comprises of short sentences or phrases that describe a typical element or prototype (Curtis et al, 2008). An example of paper prototypes designed by the participants is depicted in Figure 4.

Figure 4: Paper prototype interface example

3.4.2 Phase 2: Triading

This is the core aspect of eliciting constructs from elements without introducing bias from the lead designer and researcher. In order to eliminate bias, the participants randomly select three prototypes (triads). During triading (*see* Daniels, De Chernatony and Johnson, 1995), the researchers asked the participants to identify how two of the three prototypes are different from the third. Participants identified constructs that are important from their own perspective without any prompts from the researcher. Once the participant identified a construct, or how two prototypes are different from the third, the participants named the two polar opposites of the construct, and wrote the contrasting poles at opposite sides of a row in the grid. An example of a co-designer's grid depicted in Table 2.

Table 2: A co-designer's elicited grid

Elements positive bi-polar construct	Quick App	ReportIt App	Ubus App	FindMe App	Opposite bi-polar construct
Relevant	1	2	1	4	**Irrelevant**
Accessibility	5	3	2	5	Not accessible
Precision	3	2	1	4	No precision
Easy to use	4	3	3	4	Hard to use
Learnable	5	4	2	5	Not learnable
Total	18/25	14/25	9/25	22/25	

The participants continue the triading process to identify additional constructs for the prototypes. Participants were encouraged to change by assessing which two prototypes are alike yet different from the third. Whereas Tan and Hunter (2002) note that triading as described in the 'classic' use of RepGrid, it is not compulsory, it is a key process. Instead of simply asking the participant which user interface they like best, triading brings out the specific attributes that differentiate the user interfaces in the minds of the participants by comparing similarities in the two and contrasting from the third (Hawley, 2007).

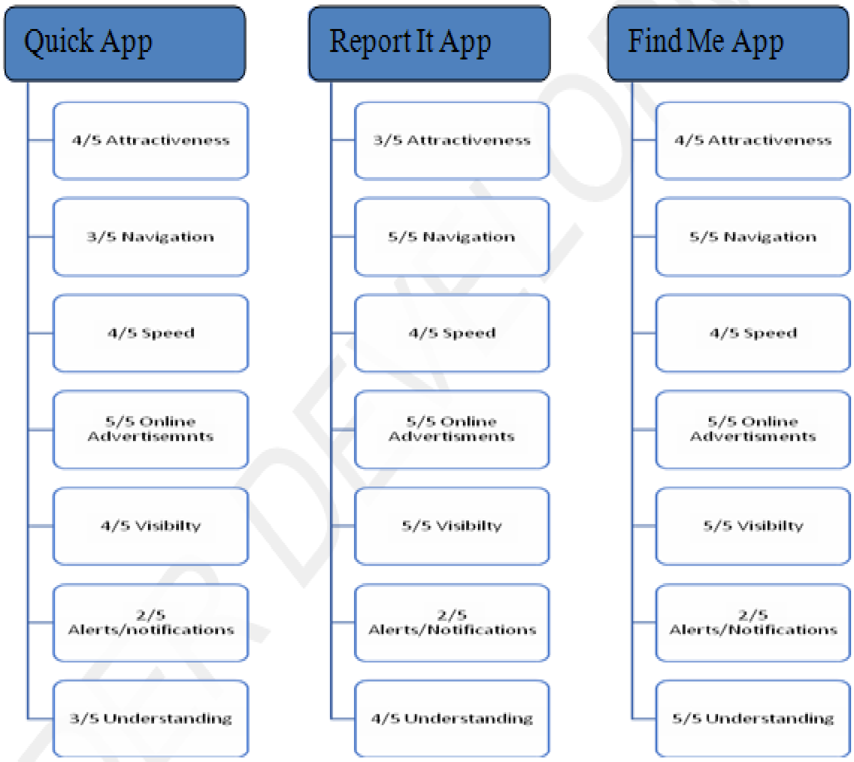
3.4.3 Phase 3: Rating and laddering

Each participant was asked to rate the constructs elicited on a seven point likert scale (1-least important through 5=most important). This study goes by Kelly's original idea (Kelly, 1955) that RepGrid help to offer explanations to account for the relationships within the grid by formulating consequent propositions. Laddering which is a technique within the RepGrid which is used to make detailed explanatory arguments in reference to the elicited constructs (Fransella, Bell and Bannister, 2004). The laddering technique helped participants to think aloud as regards the meaning and differentiation of elements and their constructs.

3.4.4 Phase 4: Analysis of Repertory Grid Data

The results of the Repertory Grid were analyzed qualitatively using Atlas Ti qualitative data analysis programme. The resultant constructs summarized from all the four prototypes as regards to how participants evaluate good or bad prototypes were coded using Atlas Ti. Notes and descriptors of the constructs provided by the participants own knowledge bases from triading were assessed to examine their understanding, knowledge and language. The participants developed a 'factor tree analysis' or 'dendrograms' to cluster elements, their constructs and ratings. Figure 5 is a sample factor tree analysis:

Figure 4: A co-designer's factor analysis tree



All the generated constructs from the four prototyped elements were analyzed using Atlas Ti. The outputs from Atlas Ti (code document, output table and network diagrams) was used a basis for our findings in respect of the cognitive criteria of perception, comprehension and projection. The rationale for the knowledge creation process in this study was through retroductive and abductive analysis.

3.5 Knowledge creation through Retroductive and abductive analysis

Advanced by Charles Sanders Peirce (1931–1958), "abduction and retroduction consists of studying the facts and devising more knowledge to explain them" (Haig, 2005) through an in-between or interplay of induction and deduction. As Meyer and Lunnay (2013) opine, using deductive inference, the theory and its associated knowledge constructs is proved or disapproved, leaving findings that lie outside the initial theoretical lens unattended to. Meanwhile, other theorists who use inductive approach argue that theories just need to emerge than imposing analytic framework a priori and therefore do not necessarily need to undertake preliminary in-depth literature and theoretical reviews (Timmermans and Tavory, 2012). Problems delaying literature and theoretical reviews during knowledge creation process are enormous. Thornberg (2012) warns that ignoring established theories and research findings implies a loss of knowledge and results into being '*atheoretical*.' As per Danermark, *et al* (2013), using abductive and retroductive knowledge creation, data beyond the proposed theoretical framework is identified and given explanatory power rather than leaving it unattended to.

Through the use of Atlas Ti to generate thematic codes based on the human cognitive information processing criteria (Endsley, 2000), the researcher and the design team conducted further data analysis by reflecting on '*what*' and '*why*' the resultant codes could fit a given criteria. Other codes created were given naming conventions based on the theoretical perspectives that guided the study. Such an abductive and retroductive interplay of coding, naming the codes, clustering the codes into code families and code families into super code families resulted into an empathetic participatory design theoretical artefact evaluation model.

4. Findings and discussions

This section offers the findings of the paper based on the research questions.

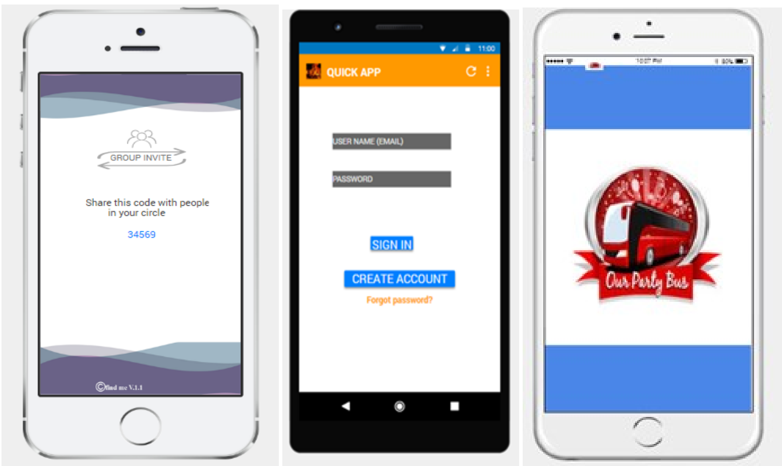
4.1 Underlying design constructs

The first question that was answered by the evidence was:
Q1: "What are the underlying design constructs, from an empathy perspective, of application interfaces during the design process?"

The number of co-design team members were N=22 participants who generated a total of 132 open codes as revealed in the word cloud in Figure 6 and output document table of open codes in Table 3.

Figure 5: Word cloud from Atlas Ti

Such a rich repertoire of constructs was used to define the elements of the four applications (Quick App, Your Bus, Report It and Find Me) whose sample interfaces are illustrated in Figure 7.



Find Me user interface **Quick App user interface** **UBus user interface**

Figure 6: Prototype application interface samples

From the word cloud constructs generated through repertory grids using abduction and retroduction analysis, the document output open code table is provided in Table 3.

Table 3: Document output open code table

Constructs generated	TOTALS:	Constructs generated	TOTALS:
Accessibility	14	Realistic design	1
Affordability	2	Relevant	10
App navigation	1	Reliability	3
Appealing colours	4	Security	5
Attractiveness	4	Sign in process	3
Authentication	1	Sophiscation	1
Capability	1	Speak and video tools	2
Dynamic motion	1	Speed	8
Easy to create an account	2	Time sharing	1
Easy to use	12	Understandability	1
Fast capability	1	Usability	1
Fast capacity	1	Usefulness	2
Flexibility	1	User confidence	2
Instant	1	User friendly	6
Interoperability	3	User interface	1
Learnable	5	Utility	3
Media sharing	4	Verification	1
Precision	1	TOTALS:	132

4.2 Categorisation of application design constructs

The second question answered by the evidence was:
Q2: "*How can the application design constructs be categorized into the cognitive criteria of perception, comprehension and projection*?

Situation awareness is commonly defined as the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future (Endsley, 1995). In order to make a wise decision in handling a system, the role of situation awareness in interface system design is to provide useable cognitive information for users (Rosli, 2015). Since users need to understand available information around them in case any unexpected incident happens for them to give immediate response, situation awareness was used to categorize the constructs into cognitive criteria of perception, comprehension and projection.

4.2.1 Perception constructs

We perceive useful or useless information from the cues in the environment. Without basic perception of important information, the odds of forming an incorrect picture of a situation within a given context increases drastically (Endsley, 2000) and this may affect the nature of constructs generated about a given designed interface. From the perception network diagram results (as generated by Atlas Ti) in Figure 8, the design team came up with perception definitions which were named by the analyst as: speed, attractiveness, time sharing, sign in process, user interface, accessibility and appealing colours.

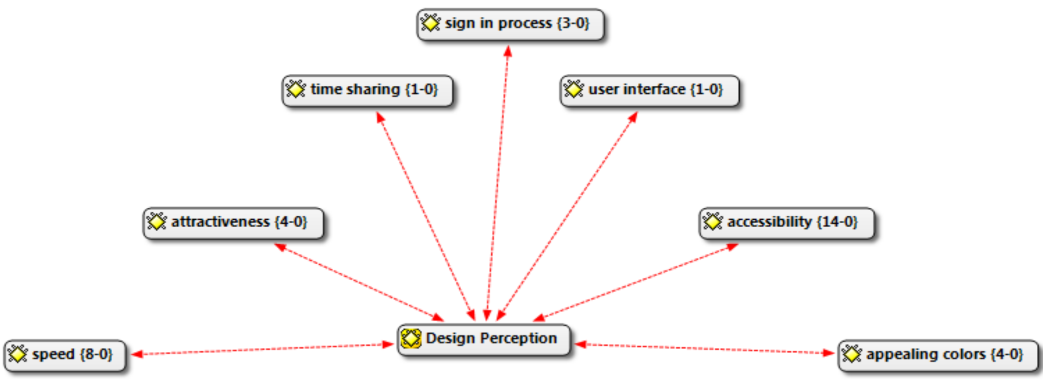


Figure 7: Perception constructs

For instance, some individuals perceive attractiveness in terms of eye catching, bright colours. Generally, participants refer to appealing colours of the interfaces as regards to attractiveness. In terms of speed, the participants considered the number of steps (interfaces) taken to complete a task submission. Other groups conceptualized it in terms length of time perceived to be taken to complete a submission online with a real system. All these constructs describing the perception variable seem to define the design aspect of an object that suggests how it should be used. McGrenere and Ho (2000) have termed these affordances. They assert, for example, that buttons with two layer images on an interface can give hints to user that the buttons are active and the user can click on them.

4.2.2 Comprehension

At comprehension level, users organize and understand the significance of the perceived information on a particular situation within a given context (Endsley, 1995). This definition is consistent with Cambridge international dictionary that define comprehension as the ability to understand completely and be aware of a situation and facts therein.

Based on the Atlas Ti network diagram results in Figure 9, the most frequent of all constructs is *ease of use*.

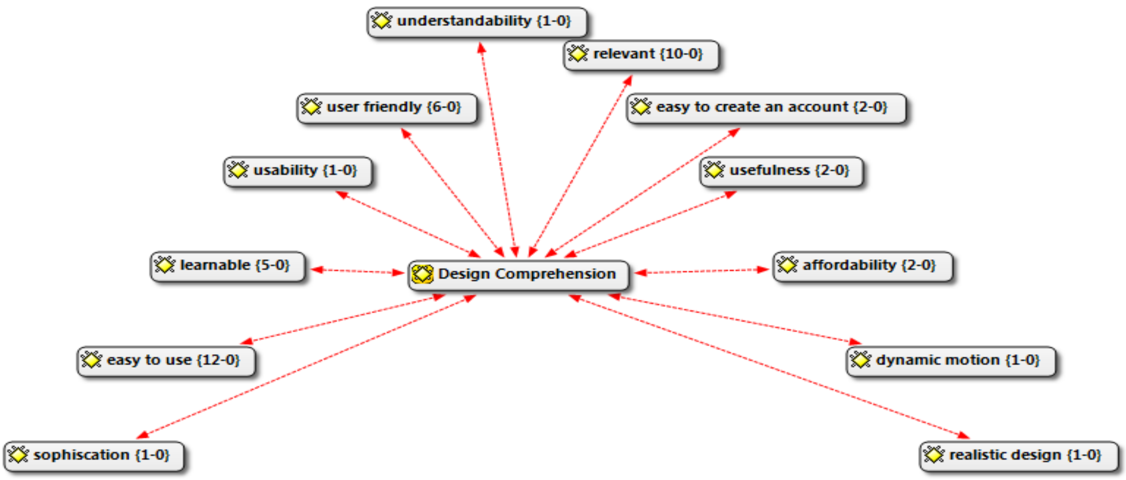


Figure 8: Comprehension constructs

From the participants' point of view, ease of use can be categorized as "fast" and "slow" thinking. One way is the "fast" way, by which we interpret information automatically and quickly, with little or no effort; the "slow" way involves effortful thinking and complex mental activities (Refined during the plenary discussion). From a designer's point of view, there is need to activate as much fast thinking as possible so that the user can perceive the interface as being "easy" and "natural." From the participants' definition of ease of use, most of them were not able to discern it from the way it is written. *Relevance* was the second most frequent construct in the Atlas Ti results. Participants conceptualized this construct given its appropriateness to solve a problem with a given situation and context. Other participants assessed the prototypes' relevance in terms of its ability to solve emergencies like fire, theft, crime.

4.2.3 Projection

Projection has been conceptualized as the ability of the designed system to guide users to give positive response while using it (Rosli, 2015). It is also conceptualized to be the status of the system in the near future (Endsley, 1988). Figure 10 shows the network diagram for projection constructs.

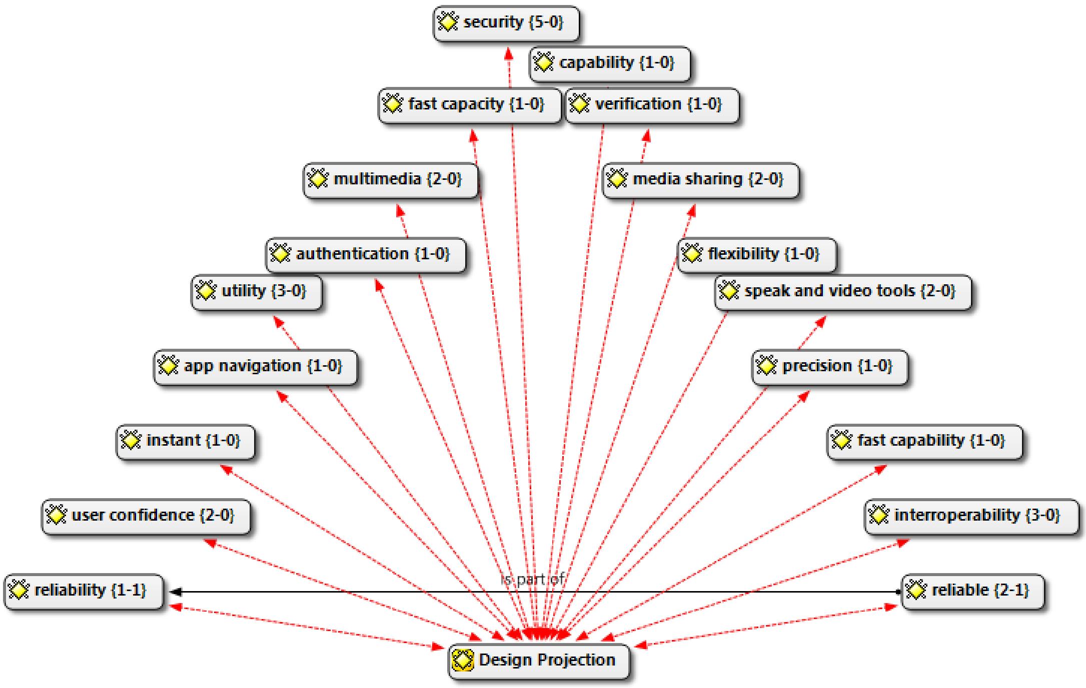


Figure 9: Projection constructs

From the findings in relation to the projection cognitive criteria, security of the application received the highest frequency. Some participants defined security in terms of vulnerability to unknown users. This was in terms of applications that lacked username options and password. Other constructs included utility, user confidence, speak and video tools, multimedia which point to some form of explicit knowledge known as interoperability as advanced by some participants. This prompted us to assess what they actually meant by the term interoperability as it did not appear to be common knowledge. For instance, some of the participants perceived interoperability to the ability of an App to '*enable users to share the contents with other similar applications and hardware*.'

4.3 Lessons from the empathetic participatory design process

The third question answered in the study was:

Q3: What key lessons can be reflected on from this empathetic participatory design process?

The following four lessons were identified:

4.3.1 Voices during participatory design process

As knowledge unfolds among the designers and users, there arise a sense of knowledge conflict (or divergence) and knowledge harmony (or convergence). For instance during convergence, the users' mental models get aligned with the designers' conceptual models. This creates empowering and motivating outcomes among the team members. There happens to be varying voices into design, reflections, conceptualizations, participation, realization and ideations. Other silent voices involve the fear by shy participants to speak anything negative or seek support during the design process. This implies that the lead designer has to listen and reach out to the less active participants to examine what goes on around their design world and internally by having a one on one consultation. Negative open criticisms need to be mitigated as it stifles initiative and creativity among adult learners. There is need to devise ways of listening to the unspoken words as the researcher moves round to observe the constructs being elicited and prompting through laddering why such naming is being proposed by a participant.

4.3.2 Balance between user expectations, insights, needs and system requirements

During participatory design, there happen to be relations, conflicts between system conceptualization and realization. Reflecting on whose voice is heard during the design research process yields divergences and convergences. Some of the divergences emanated from user needs and mental models being different from designer experiences. Divergence would result into frustration which in turn results into convergence and a sense of "*I now see*." This would further result into fruitful discussions about project boundary, clearly articulating differences between needs and requirements, significance of context and the importance of giving users an accurate picture of the project.

4.3.3 Openness and participatory design

Openness nurtures exchange of possible knowledge and practices. Openness can be at different phases of the design process: in project time (open knowledge exchange during participatory design process) and user time (open knowledge exchange after participatory design). Openness is crucial when a user gains access to system functionalities so that the evolving design gets improved. Openness involves sharing knowledge, prototypes, software, hardware or processes which can be comparative to sharing scientific information, during which it is necessary to build in existing knowledge and exchange.

4.3.4 Motivation for participatory design

During empathetic participatory design process, there is need to ascertain that the team members have empowered capabilities and competencies, also termed as psychological empowerment (Zimmerman and Rappaport 1988). To have sustained motivation through the design process, the researcher trained the co-design team members; built their competencies to design low, middle and high fidelity prototypes. According to the co-design participants, it was an exciting and energizing experience and was observed from the evolving prototypes they developed from paper, to high fidelity simulation prototypes. It has been observed that the training embedded in the participatory design process serves as an incentivising mechanism to motivate and empower the people who originally never had such a skill. This improves and enhances their capabilities and functionings (Sen, 2005).

5. Conclusion

The premise of the research problem which underpinned this study was that even though there are a growing number of ICT applications becoming available to end-users across all walks of life, too few designers incorporate the user in the design process. The study demonstrates that the application of a co-design framework was able to generate tacit and explicit knowledge. The underlying constructs generated by co-designer team members through reciprocation of tacit and explicit knowledge during construct elicitation included perception, comprehension and projection constructs. Crucial perception constructs were system accessibility, system speed and interface attractiveness.

As regards to comprehension, this study renders support to other studies that reveal that ease of use, user friendliness and relevancy are crucial knowledge constructs for system evaluation.System security and reliability were key knowledge constructs in respect of projection. As has been observed, naming of such constructs was guided by both tacit and explicit knowledge of the co-design team members during empathetic design process. Such knowledge constructs result into varying ICT adoption levels.

Key lessons learnt in this study is that there are divergent and convergence voices during participatory design process that result into refinement of knowledge constructs created. Some of the divergences emanated from user needs and mental models being different from designer experiences. There is need to enhance openness and motivate the co-design team members through ongoing trainings for further knowledge creations. This study finally offers support to Nonaka and Takeuchi (1995) by arguing that tacit and explicit knowledge are reciprocal during the process of participatory design outcome enrichment.

References

Alexander, P., van Loggerenberg, J., Lotriet, H. and Phahlamohlaka, J., 2010. The use of the repertory grid for collaboration and reflection in a research context. *Group Decision and Negotiation*, *19*(5), pp.479-504.

Andriessen, D., 2006, August. Combining design-based research and action research to test management solutions. In *7th World Congress Action Research*.

Bedny, G. and Karwowski, W., 2003. A systemic-structural activity approach to the design of human-computer interaction tasks. *International Journal of Human-Computer Interaction*, *16*(2), pp.235-260.

Bedny, G. and Meister, D., 1999. Theory of activity and situation awareness. *International Journal of cognitive ergonomics*, *3*(1), pp.63-72.

Björklund, L., 2008. The Repertory Grid Technique: Making Tacit Knowledge Explicit: Assessing Creative Work and Problem Solving Skills.

Burns, C.M., Skraaning Jr, G., Jamieson, G.A., Lau, N., Kwok, J., Welch, R. and Andresen, G., 2008. Evaluation of ecological interface design for nuclear process control: situation awareness effects. *Human factors*, *50*(4), pp.663-679.

Bovill, C. and Bulley, C.J., 2011. A model of active student participation in curriculum design: exploring desirability and possibility.

Bovill, C., Bulley, C.J. and Morss, K., 2011. Engaging and empowering first-year students through curriculum design: perspectives from the literature. *Teaching in Higher Education*, *16*(2), pp.197-209.

Butt, T., 2004. Understanding, explanation, and personal constructs. *Personal Construct Theory & Practice*, *1*(1), pp.21-27.

Cook, S.D. and Brown, J.S., 1999. Bridging epistemologies: The generative dance between organizational knowledge and organizational knowing. *Organization science*, *10*(4), pp.381-400.

Coughlan, P., Suri, J.F. and Canales, K., 2007. Prototypes as (design) tools for behavioral and organizational change: A design-based approach to help organizations change work behaviors. *The journal of applied behavioral science*, *43*(1), pp.122-134.

Curtis, A.M., Wells, T.M., Higbee, T. and Lowry, P.B., 2008. An overview and tutorial of the repertory grid technique in information systems research.

Danermark, B., Granberg, S., Kramer, S.E., Selb, M. and Möller, C., 2013. The creation of a comprehensive and a brief core set for hearing loss using the international classification of functioning, disability and health. *American journal of audiology*, *22*(2), pp.323-328.

Daniels, K., De Chernatony, L. and Johnson, G., 1995. Validating a method for mapping managers' mental models of competitive industry structures. *Human Relations*, *48*(9), pp.975-991.

Davis, F.D., 1993. User acceptance of information technology: system characteristics, user perceptions and behavioral impacts. *International journal of man-machine studies*, *38*(3), pp.475-487.

de Souza, D.E., 2013. Elaborating the Context-Mechanism-Outcome configuration (CMOc) in realist evaluation: A critical realist perspective. *Evaluation*, *19*(2), pp.141-154.

Druin, A. and Fast, C., 2002. The child as learner, critic, inventor, and technology design partner: An analysis of three years of Swedish student journals. *International Journal of Technology and Design Education*, *12*(3), pp.189-213.

Druin, A., 2010. Children as codesigners of new technologies: Valuing the imagination to transform what is possible. *New Directions for Youth Development*, *2010*(128), pp.35-43

Easterby-Smith, M., 1980. The design, analysis and interpretation of repertory grids. *International Journal of Man-Machine Studies*, *13*(1), pp.3-24.

Ellis, R.D. and Kurniawan, S.H., 2000. Increasing the usability of online information for older users: A case study in participatory design. *International Journal of Human-Computer Interaction*, *12*(2), pp.263-276.

Endsley, M. R. 1995. *Towards a Theory of Situation Awareness In Dynamic Systems, Human Factors.* 37(1), pp.32-64. IEEE Xplore.

Endsley, M.R. and Garland, D.J., 2000. Theoretical underpinnings of situation awareness: A critical review. *Situation awareness analysis and measurement*, *1*, p.24.

Endsley, M.R., 1997. The role of situation awareness in naturalistic decision making. *Naturalistic decision making*, *269*, p.284.

Fischer, G. and Ostwald, J., 2005. Knowledge communication in design communities. In *Barriers and biases in computer-mediated knowledge communication* (pp. 213-242). Springer, Boston, MA.

Fransella, F., Bell, R. and Bannister, D., 2004. *A manual for repertory grid technique*. John Wiley & Sons.

Gurstein, M., 2003. Effective use, local innovation and participatory design. *First Monday*, *8*(12).

Haig, B.D., 2005. An abductive theory of scientific method. *Psychological methods*, *10*(4), p.371.

Hawley, M., 2007. The Repertory Grid: Eliciting user experience comparisons in the customer's voice.

HK, M., Walter, G.F., Brandis, A., Stan, A.C. and Ammann, A., 1999. The interactive use of networking multimedia-innovative education resource for professionals and patients. In *Medical Informatics Europe'99* (Vol. 99, p. 467). Ios Pr Inc.

Hunter, M.G. and Beck, J.E., 2000. Using repertory grids to conduct cross-cultural information systems research. *Information Systems Research*, *11*(1), pp.93-101.

Jagosh, J., Macaulay, A.C., Pluye, P., Salsberg, J., Bush, P.L., Henderson, J., Sirett, E., Wong, G., Cargo, M., Herbert, C.P. and Seifer, S.D., 2012. Uncovering the benefits of participatory research: implications of a realist review for health research and practice. *The Milbank Quarterly*, *90*(2), pp.311-346.

Kelly, G., 1955. The psychology of personal constructs (New York, WN Norton and Company Inc).

Kim, H.W., Chan, H.C. and Gupta, S., 2007. Value-based adoption of mobile internet: an empirical investigation. *Decision support systems*, *43*(1), pp.111-126.

Kouprie, M. and Visser, F.S., 2009. A framework for empathy in design: stepping into and out of the user's life. *Journal of Engineering Design*, *20*(5), pp.437-448.

Kyakulumbye, S., Pather, S. and Jantjies, M., Creating Knowledge in the Design Thinking Process: Reflections on Participatory Design. In *ICICKM 2018 15th International Conference on Intellectual Capital Knowledge Management & Organisational Learning* (p. 132). Academic Conferences and publishing limited.

Lawson, T., 1997. Economics and reality.

Lee, J.D. and See, K.A., 2004. Trust in automation: Designing for appropriate reliance. *Human factors*, *46*(1), pp.50-80.

Lindsay, S., Brittain, K., Jackson, D., Ladha, C., Ladha, K. and Olivier, P., 2012, May. Empathy, participatory design and people with dementia. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 521-530). ACM.

McFadyen, M.A. and Cannella Jr, A.A., 2004. Social capital and knowledge creation: Diminishing returns of the number and strength of exchange relationships. *Academy of management Journal*, *47*(5), pp.735-746.

McGrenere, J. and Ho, W., 2000, May. Affordances: Clarifying and evolving a concept. In *Graphics interface* (Vol. 2000, pp. 179-186).

Meyer, S.B. and Lunnay, B., 2013. The application of abductive and retroductive inference for the design and analysis of theory-driven sociological research. *Sociological Research Online*, *18*(1), pp.1-11.

Mezirow, J., 1993. A transformation theory of adult learning. In *Adult Education Research Annual Conference Proceedings* (pp. 141-146).

Moraine, M., Duru, M., Nicholas, P., Leterme, P. and Therond, O., 2014. Farming system design for innovative crop-livestock integration in Europe. *Animal*, *8*(8), pp.1204-1217.

Morecroft, J.D., 1985. Rationality in the analysis of behavioral simulation models. *Management Science*, *31*(7), pp.900-916.

Muller, M.J. and Druin, A., 2010. Participatory design: the third space in hci. human-computer interaction: Development process. J. Jacko and A. *Sears. Eds. Handbook of HCI*.

Napier, N.P., Keil, M. and Tan, F.B., 2009. IT project managers' construction of successful project management practice: a repertory grid investigation. *Information Systems Journal*, *19*(3), pp.255-282.

Nardi, B.A. ed., 1996. *Context and consciousness: activity theory and human-computer interaction*. mit Press.

Nehme, C.E., Scott, S.D., Cummings, M.L. and Furusho, C.Y., 2006, October. Generating requirements for futuristic hetrogenous unmanned systems. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 50, No. 3, pp. 235-239). Sage CA: Los Angeles, CA: SAGE Publications.

Nonaka, I. and Takeuchi, H., 1995. The knowledge creation company: how Japanese companies create the dynamics of innovation.

Norman, D.A., 1988. The design of everyday things. *Doubled Currency*.

Norman, D.A., 1999. Affordance, conventions, and design. *interactions*, *6*(3), pp.38-43.

Pawson R (2013) The Science of Evaluation: A Realist Manifesto. Thousand Oaks, CA and London: SAGE.

Pawson, R. and Tilley, N., 1997. An introduction to scientific realist evaluation.

Petersen, E.J., 2017. Empathetic user design: understanding and living the reality of an audience. *Communication Design Quarterly Review*, *4*(2), pp.23-36.

Preece, J., Rogers, Y. and Sharp, H., 2015. *Interaction design: beyond human-computer interaction*. John Wiley & Sons.

Qureshil, S., Kamal, M. and Wolcott, P., 2009. Information technology interventions for growth and competitiveness in micro-enterprises. *International Journal of E-Business Research (IJEBR)*, *5*(1), pp.117-140.

Rosli, D., 2015. Cognitive Awareness Prototype Development on User Interface Design. *TOJET: The Turkish Online Journal of Educational Technology*, *4*(2), pp.32-40.

Rosli, D.I., Alias, R.A. and Rahman, A.A., 2012. Cognitive task analysis method for system interface design. *Journal of Research and Innovation in Information Systems*, pp.1-8.

Rossi, F. and Rosli, A., 2015. Indicators of university–industry knowledge transfer performance and their implications for universities: evidence from the United Kingdom. *Studies in Higher Education*, *40*(10), pp.1970-1991.

Sanders, E.B.N., 2003. From user-centered to participatory design approaches. In *Design and the social sciences* (pp. 18-25). CRC Press.

Sen, A. K. 1999. Development as freedom. New York: Knopf.

Sin Tan, K., Choy Chong, S., Lin, B. and Cyril Eze, U., 2009. Internet-based ICT adoption: evidence from Malaysian SMEs. *Industrial Management & Data Systems*, *109*(2), pp.224-244.

Soo, C., Devinney, T., Midgley, D. and Deering, A., 2002. Knowledge management: philosophy, processes, and pitfalls. *California management review*, *44*(4), pp.129-150.

Staunstrup, J. and Wolf, W., 2013. *Hardware/software co-design: principles and practice*. Springer Science & Business Media.

Stolterman, E., 2008. The nature of design practice and implications for interaction design research. *International Journal of Design*, *2*(1) accessed http://www.ijdesign.org/ojs/index.php/IJDesign/article/view/240/148 on October 2017

Tan, F.B. and Hunter, M.G., 2002. The repertory grid technique: A method for the study of cognition in information systems. *Mis Quarterly*, pp.39-57.

Thimbley, H. 1998. *User Interface Design.* ACM Press. New York: Addison Wesley

Thornberg, R., 2012. Informed grounded theory. *Scandinavian Journal of Educational Research*, *56*(3), pp.243-259.

Timmermans, S. and Tavory, I., 2012. Theory construction in qualitative research: From grounded theory to abductive analysis. *Sociological Theory*, *30*(3), pp.167-186.

Van Aken, J.E., 2005. Management research as a design science: Articulating the research products of mode 2 knowledge production in management. *British journal of management*, *16*(1), pp.19-36.

van Os, G. and van Beurden, K., 2014. Personas and Role-Play Help Students (and Designers) Experiencing Reality. In *DS 78: Proceedings of the 16th International conference on Engineering and Product Design Education (E&PDE14), Design Education and Human Technology Relations, University of Twente, The Netherlands, 04-05.09. 2014*.

Verdegem, P. and Verhoest, P., 2009. Profiling the non-user: Rethinking policy initiatives stimulating ICT acceptance. *Telecommunications Policy*, *33*(10-11), pp.642-652.

Wessler, R. and Ortlieb, M., 2002, September. A user centred approach to measure a web site's appeal using the repertory grid technique. In *Proceedings of the 1st European UPA conference on European usability professionals association conference-Volume 3* (pp. 70-78). British Computer Society.
Wright, P. and McCarthy, J., 2004. *Technology as experience*. Cambridge, MA: MIT Press.
Wyche, S., 2015, May. Exploring mobile phone and social media use in a Nairobi slum: a case for alternative approaches to design in ICTD. In *Proceedings of the Seventh International Conference on Information and Communication Technologies and Development* (p. 12). ACM.
Wynn Jr, D. and Williams, C.K., 2012. Principles for conducting critical realist case study research in information systems. *MIS quarterly*, pp.787-810.
Zimmerman, M.A. and Rappaport, J., 1988. Citizen participation, perceived control, and psychological empowerment. *American Journal of community psychology*, *16*(5), pp.725-750.