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TRANSITION FROM OBJECT TO ACTIVITY: PRODUCT DESIGN KNOWLEDGE MODELS

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ABSTRACT:

The traditional interactive roles of the designer, client and consumer (user) are becoming more complex. Consumers are changing from passive, to active and connected. They are sophisticated and knowledgeable regarding their demands. Consumers, designers and clients are now co-designing. This means that different knowledge is needed in order to design better and more valuable products/ interfaces and systems that will respond to contemporary demands. The design paradigm shift — from an object to activity — is emerging at different levels. This paper focuses on the activity-centred approach and identifies new product design knowledge necessary for this approach. It clarifies the emergent product design knowledge and presents descriptive models of the connections between this and existing product design knowledge. Finally, the paper outlines directions for domain-specific knowledge generation within the social framework — consisting of *people, culture, context and activity* — by researching various levels of human engagement.

Keywords: activity, design knowledge, knowledge models

1. INTRODUCTION

This research addresses the issue of the constant transition of product design influenced by technological, social, economic and political changes. Computer Aided Design (CAD) and Computer Aided Manufacture (CAM), stereo lithography (SL), virtual reality (VR), new material development, biotechnology and concurrent engineering have had an impact on the profession and its services. The World Wide Web and networking are changing the traditional ways of communication and learning. Society is slowly transforming and more products and services are available than ever before. Their variety is overwhelming consumers (users) and does not necessarily bring better experiences (Prahalad and Ramaswamy 2004). According to Prahalad and Ramaswamy (2004:1), there is evidence of "discontinuities in the competitive landscape and connectivity, technology convergence and globalisation are blurring the boundaries of product definitions". It is no longer possible to focus on cost alone, and consumer (user) involvement is changing from passive to active and connected (2004:2). Consumers have developed their own independent network communities where they exchange their experiences and experiment with products. They are becoming active, sophisticated and knowledgeable in relation to their demands.

This dynamic is causing an emerging interaction between the company and consumers (users). They expect to be part of the design and development process and to participate in co-design of an artifact. Their values shift from consumption of a traditional physical product to the total experience of systems. The design and development of products/ systems is moving from 'product-centric' to 'consumer (user) experience-centric' (Prahalad and Ramaswamy 2004). This has a subsequent impact on design practice as the traditional designer/ client role itself becomes more complex and interactive. Co-designing by client and consumer (user) has emerged. This means that different knowledge is needed in order to design better and more valuable products, interfaces or systems that will respond to contemporary consumer demands. The design paradigm shift from object to activity and experience is evident at many different levels (Findeli 2001, Popovic 2005) and has become a challenging concept for the product design community. This emerged environment requires cross-disciplinary teams and integrated design solutions.

This paper discusses this complex, changing environment of professional practice and recognises the resultant need for new knowledge that will equip designers to better understand the changing relationship between client, designer and user. It recognises the need for knowledge of various levels of human activity and engagement in the new activity-centred design process. Building on earlier modelling of the (traditional) product-centred design process (Popovic 2002), it presents

the Activity- centred Knowledge Connection Model to both identify and support the domain-specific knowledge essential to the contemporary design process.

2. THE CHANGING CONTEXT OF PROFESSIONAL PRACTICE

Professional industrial (product) design work varies from country to country and depends on the industrial development of that particular country. Current professional practice indicators that give some reliable information about industrial design service providers (designers) and the industrial design service users (client/ industry), are based on the data available on the Core77 (2005) web site. The research is based on current knowledge of industrial (product) design practices. It investigates the services and skills they offer in three contexts: (i) global — the *knowledge in use* in an overall context, undifferentiated by location; (ii) regional — *knowledge differences* between developed and newly industrialised countries and (iii) local - *knowledge utilisation* comparison between global sites and Australian sites. Sample websites provide data for three analytical groupings of professional knowledge: at the global level of operation, at the level of economic development of a group of countries, and at the local (Australian) level. For the global search of design practices (Coroflot 2005), a randomised selection of design companies was made. Out of 2289 sites listed, 47 sites were analysed. This method of randomly selecting the site was to display the Coroflot listing in pages of fifty companies. Every fiftieth site was analysed, beginning at the third site. Some sites were not included in the data if the page was not available for copying. If a site was rejected for one of these reasons, then a site close in the list to the target site was substituted. Using this method of selection, forty seven sites were found to be suitable for analysis. In the analysis of countries, seventy-three countries were represented (Coroflot 2005). The countries were divided into those with a developed economy, and those whose economy was newly industrialized. Not all countries in the developing nations were selected for analysis. Because search returns varied in quantity across countries, it was decided to analyse only 2.5% of sites returned when searching by country. For a more defined analysis at a local level, professional knowledge was assessed by using one country at the local level, Australia. Twelve sites in Australia were found suitable for analysis.

Once the web sites for content analysis were chosen, they were probed for information about three criteria: (i) the company vision, (ii) services offered and (iii) projects. Each of the three criteria contributed to analysis in each of the three levels of global scale. N-Vivo verbal data analysis software was used to assist in coding and analysis. Ten themes emerged during the

coding and analysis. The most frequent themes were: economic consideration (59%), client consideration (51%), ethical values (47%), human dimensions (36%), knowledge (36%), design process (29%) and teamwork (12%). The user appeared as an important factor. There is a sense that designers understand and are sensitive to the user's needs. However, the emphasis was on the client becoming a part of the design team. There is a suggestion that the customers (users) have their own objectives, values and expectations that are to be satisfied by the designers. It is demonstrated that *working together with a client* (51%) is important. The sites emphasise that they utilise *the design process* (29%) from idea generation to manufacture or point of sale. Some specific parts of the process are mentioned, such as testing, task analysis and measurement. Knowledge of the *complete design process* is emphasised, such as "from ideas to final delivery and feedback stage". The knowledge and capabilities of the companies include the specialisations and experience of the team. Knowledge is represented as a *general understanding of the design process*. It is more concerned about ways of applying the knowledge than explicit mention of the type of knowledge held by the company. In the countries with emerged economies, 'knowledge' refers to practical knowledge, in reference to a multi-disciplinary, cross disciplinary approach. It seems that this refers to designers' versatility: their ability to do a variety of work, with a wide knowledge span.

It is seen that more than half the companies do *design research.* Some companies mention cognitive studies, ethnography and focus groups as services. If this figure is extrapolated to represent a proportion of the entire listing on Coroflot, then more than one thousand of the Coroflot companies could be using these methods. This is similar across all three levels of analysis. However, at the local level (Australia), design research is directed toward market niches. The earlier study conducted – using the same data from Coroflot (Popovic 2001a) – indicated that design research (3%) was emerging then. The current study is supporting its expansion. The same study identified the emerging areas of expertise within service or project domains (Table 1). The new study concurs by identifying these services from a content analysis of the overall context, undifferentiated by location. The emerged areas are present within (ii) services offered and (iii) projects (Coroflot 2005).

In summary, knowledge utilisation by professional practices is demonstrated through the design process, the expansion of design research and emerged services offered. This demands a higher level of expertise at various domains – from research to development and commercialisation. However, the research conducted demonstrates that the majority of practices are still working within the classic designer-client relationship. Nevertheless, the new areas within the industrial

design practices (Table 1) have established the foundation of the changing context. They have indicated the need for new knowledge to support the changing relationship between client, designer and customer (user). Therefore, each of these new areas (Table 1) requires knowledge of various levels of human activity to be integrated into the design process. Integration of knowledge about activities into an artifact design requires an understanding of people's daily engagement and what is that that influencing object transformation to experience – activity-centred design.

Table 1 New areas within industrial (product) design practices

experience design	scenario design
design leadership	strategic planning
industrial design strategy	strategy innovation
interaction design	user research
technology and innovation management	virtual visualisation

3. OBJECT-TO-ACTIVITY TRANSITION

This paper identifies some of the changing forces that are influencing the direction of product design practice. Business diversification and the integration of product and services into complex systems with knowledge shared between the users/ customers and clients, demand more detailed research. This view is also supported by the work paradigm shift with work now charactrised as nonlinear, dynamic, collaborative, knowledge and team driven. This new work paradigm, in turn, supports better interaction between designers and other members of collaborative teams. The development of new technological tools further enables designers to work concurrently with other team experts. However, the resultant, emerged design areas (Table 1) each demands new methods, knowledge and strategies. These areas are operating within the social context; they provide diverse levels of interaction and engagement with artifacts. These engagements are social or emotional where products/ systems are mediating the interaction and supporting various experiences.

People's experiences with products/ systems are influencing their perception. Responses such as "it feels good", "that is right", "cool", "cute" or "looks different", are popular attributes that people assign to a product after or during an interaction. They convey many qualitative values which make some products and systems contribute to the enhancement of an experience within the activity and its transformation (Nardi 1996). When people see products or experience systems

they make a “perceptual categorisation” (Clancey 1999) of visual form or interface. Thus, visual aspects play an important part in developing a user's concept and contribute to an interaction experience.

There are many different approaches that have been used to assist in understanding human interaction and experience. The term “interaction design” is defined by Winograd (1996) as “the design of spaces for human communication and interaction”. Within the context of this paper, interaction is very broadly defined and refers to *various levels of human engagement.* The recent direction of incorporating activity within the design process has lead to “activity based” or “activity-centred” interaction (Norman 1998). This attempts to challenge designers to design artifacts within an activity. However, within any activity, people have social engagement, be it at work or leisure. They are linked on a social and individual level (Nardi 1996). The activities are in constant change; this influences a product/ system transformation (Kuutti 1996). Any developmental process of an activity can generate a new activity (Nardi 1996). This is achieved through different actions. This means that the design can be seen as an agent for change. It is trying to change the activity by introducing a new activity, which may lead to an innovative design and new challenge (eg. transformation of a telephone to iPhone).

In studying the activity, one needs to refer to the Activity Theory concept which emphasises the shared context, including “the social, emotional, cultural and creative dimension of human actors” (Kaptelinin and Nardi 2006:6). Social structures play an important part in any activity (Nardi 1996). These include users, organisations and their cultural and environmental structures. It is very important for designers to understand the process that occurs behind the activity. The new designs should challenge their users to enjoy different levels of interaction. They should experience new pleasure every time they interact with or use the product/system. The design of the dynamic structures of products/ systems supports exploration, flexibility and adaptability during interaction. The concept of *“form follows function”* is evolving to *“form follows pleasure” to "form follows interaction"* (Popovic 2001b) to "*form follows experience" and “form follows activity”.*

Design of artifacts/ systems provides organisations of interfaces and controls based on logical organisation, following task analysis patterns. However, they fail to support activity patterns (Norman 2006). Designers think about the ‘correct’ order in which the activities are undertaken. They rarely think about unusual circumstances and new situations. People’s engagements with technologies generate new activities and require designers’ understanding. The product/ systems do not exist in isolation; they are activity and situation dependent. People’s experiences with them

play a significant part in new knowledge generation. There are studies relating to how tools mediate between the user and object and state: “tools mediation is a way of transmitting cultural knowledge” (Kaptelinin 1996: 45-68). This is an example of implicit learning using objects. Indeed, “…some cultural anthropologists have long seen the artifacts we create as the medium through which cultural identities are preserved and communicated to subsequent generations”. Others go so far as to “equate culture with the artifacts a society uses” (Krippendorff 1990). Nardi (1996) believes that “all human experience is shaped by the tools and sign systems we use”. Tools shape users’ activity and can even influence their goals. Suchman (1987) points out that an activity would grow out from the situation. The main idea that artifacts mediate the activity was introduced by Kuutti (1991). Its theoretical construct has been transferred to the product/ system concept where artifacts are mediators of knowledge generation and utilisation. This leads to better understanding of people’s engagements and experiences. In order to determine where and how this new knowledge will be applied into an artifact design, one needs understanding of design expertise and how the emerged knowledge interacts on an artifact concept level.

4. DESIGN EXPERTISE AND EMERGED KNOWLEDGE

The study of expertise is founded on the study of how experts process information, and how domain – specific knowledge is represented during problem solving. There is evidence supporting the differences between novice and expert in knowledge representation, processing and use. Expert performances have been studied in many different domains and different scientific approaches have been used to investigate outstanding performance (Ericsson and Smith 1991). In general, expertise is "by definition, the possession of a large body of knowledge and procedural skills" (Chi, Glaser and Rees 1982). The expertise approach stands on the premise that acquired characteristics contribute significantly to an outstanding performance (Ericsson and Smith 1991). Recent studies in human expertise show that experts are not always outstanding in their performance, as they can be less accurate in decision making.

It has been recognised that the distinctions between novices and experts are the body of domain knowledge that experts have and the fact that experts access that knowledge in more efficient ways than novices do (Kolodner 1983). The development from novice to expert should be understood as a three-stage process (Patel and Groen 1991): (i) development of adequate knowledge; (ii) development of ways of distinguishing between relevant and irrelevant information and (iii) learning how to use these relevant representations in an efficient way. It is important to

note that the improvement of human performance is in direct relation to the amount of practice that is done.

Therefore, experience plays an important role in problem solving (Visser 1996, Kolodner and Simpson 1986, Cross 2006). These authors illustrate that experience contributes to problem solving activity and brings modifications to its associated reasoning processes. In cases of successful experience, already-known principles are reinforced and improper ones modified. In some cases, "individual experience acts as exemplars upon which to base later decision" (Kolodner and Simpson 1986). Visser (1996) studied the use of “episodic” knowledge which is "particular experience-linked sources" in design-related problem solving. She found that a designer uses personal and other people's experience during the problem solving activity. In this case, previous experience can help in deciding procedures to be followed or avoided. It can help to predict design outcomes and the steps to be taken in situations. It may help in selecting and applying situational knowledge chunks to a particular design task domain. The most recent studies in human expertise demonstrate the importance of situation and context. They demonstrate a much broader view of the approach to human expertise and expert knowledge acquisition and utilisation (Feltovich, Ford and Hoffman 1997). They also take into account the importance of social condition and the context in which an activity occurs.

During the last thirty years, a significant amount of research into the study of design activity has been undertaken. This research defends the notion that design ability should be regarded as a discipline in its own right (Cross 1995, 1999a, 2006). According to Cross (1995), designers do the following: (a) produce novel solutions, (b) work with incomplete information, (c) use drawings and other media as part of the problem solving and (d) apply imagination to problem solving. The process of designing involves the generation of ideas which lead to new understanding (Greeno 1978). In depth knowledge is required to provide a structure for ill-defined problems and reach an appropriate design solution. According to Michell (1985) this includes: (a) knowledge of implementation methods for generating possible solutions; (b) control knowledge for guiding the search for satisfactory design and (c) knowledge of monitoring and evaluating one’s own design process. Simon (1984) identifies that ill-structured tasks utilise domain-specific knowledge and knowledge for organising the overall solution process. This recognition of the significance of the process of designing concurs with professional practice’s representation of knowledge. Designers utilise knowledge and strategies to execute the tasks and monitor the design process.

Studies about domain – specific knowledge exist. They *are from* well-structured domain (Chi, Glaser and Farr 1988; Chi, Felltovich and Glaser 1981; Larkin at al.1980) or ill-structured domain as design (Cristiaans 1992, Venselaar 1987) or user studies (Popovic 1998). They all demonstrate that detailed domain-specific knowledge is necessary in order to solve problems or achieve an innovative outcome. Without domain-specific knowledge, a person will not be able to contribute to a multidisciplinary team. Design is categorised here as an *adaptive expertise*. Designers adjust to the design tasks by utilising their knowledge which they adapt and apply to the current tasks during the design process (Suwa, Gero and Purcell 1999).

It is understood that, for a designer to derive any solution, the knowledge of strategies, domain-specific knowledge and general process knowledge are required (Christiaans 1992). The sources of design knowledge are people, processes, products (Cross 1999) and activities and their context (Popovic 2000). In the context of design (product design), expertise is *"understood as possession of a body of knowledge and the creative and analytical ability to extract, analyse and apply relevant knowledge"* (Popovic 2004). Cross (2006) identifies similarities in the expert designer's strategic approach, and presents a general model of creative thinking of outstanding designers (2006:74). He points out that this "does not mean that the expert can switch practice between domains" (2006:75). This supports the notion of the importance of domain-specific knowledge and that the design domains are essential for professional development. However, experts recognised within the profession, do not always perform as experts (Ericsson at al. 2006). In summary, expertise is needed to understand and integrate knowledge of people's engagement and interaction into the artifact design.

This knowledge should become domain knowledge when designing for an experience. Therefore, it is envisaged that the knowledge connection models (Section 5) will have the capacity to support a better understanding of, and illustrate the importance of, domain knowledge during the design process.

5. EARLIER PRODUCT-CENTRED MODELS

In the earlier study of expertise development in industrial (product) design, the descriptive expert designer's knowledge connection model was developed. The model demonstrates the links between general knowledge and strategies, and their interaction with the domain-specific knowledge across two design domains – product and information design (Popovic 2002). The

integrated knowledge connection models (Popovic 2002) demonstrate the previous model's adaptability and support the notion of design being an "adaptive expertise". As "adaptive experts", designers are able to adjust to situations and apply new procedures by utilising their expert knowledge. The models clarify the utilisation of domain-specific knowledge within the early stage of the design process. The studies presented earlier (Popovic 2002, 2004) are based on the hypothesis that the images and other visuals used by the designers might convey the strategies and knowledge representation within and across design domains. Within the earlier research, strategic knowledge refers to knowledge of processes and strategies that are used during acquisition or utilisation of knowledge (Alexander and Judy 1988). Strategies are associated within the domain and across the domains. Two categories have been identified – "goal-limited" and "general" strategies (Pressley et al. in Alexander and Judy 1988). Goal-limited strategies (GLS) include processes that are relevant to accomplish tasks, while general strategies (GS) are applied on a broader level and interact with goal-limited strategies (Alexander and Judy 1998, Popovic 2002).

The objective of the earlier study was to illustrate "the connections between general knowledge and strategies and how they interact with domain-specific knowledge" (Popovic 2004:527). Novices and expert designers' visuals generated during the early stage of the design project were coded and analysed. The designers had dated and archived all visuals. The visuals were divided into segments and the coding was done by one person and was repeated three times with an interval break of one week between the coding. The coding scheme was based on the identification of design constraints (criteria) and on the way designers grouped them during the design process. Therefore, the following have been coded and identified:

- *general strategies (GS)*: strategies applied to integrate GLS into a satisfactory design outcome;
- *goal-limited strategies (GLS)*: processes relevant to accomplish tasks that relate to "chunks" of design constraints (criteria); in the case of an expert designer, they are grouped together into large complex "chunks";
- *domain-specific knowledge (DSK)*: knowledge applied that contributes to a satisfactory design outcome;
- *experiential knowledge (EK)*: knowledge acquired during previous experiences;

- *knowledge interaction*: interaction of domain-specific knowledge (DSK) and experiential knowledge (EK) with goal-limited strategies (GLS)

Only the expert knowledge connection model is used in this study (Popovic 2004). The expert designer's work is selected from the educational and professional context: post graduate students and professional designers with five to ten years practical experience in product design. To design a product, expert designers rely on immediate knowledge processing to understand design constraints. Behind this analysis and these skills is a demonstration of experiential and domain-specific knowledge developed through an intensive practice. Decomposition, integration and interpretation of constraints occurred at the early stage. The designers grouped the constraints into related and manageable "chunks" (goal-limited strategies) and applied relevant integration strategies. They then connected this with relevant domain-specific (DSK) and experiential knowledge (EK).

The earlier research identifies that the expert industrial designer is equipped with (i) a rich content of goal-limited strategies (GLS); (ii) *very* large "chunks" of design constraints; (iii) domain-specific knowledge (DSK); (iv) very weak assumptions (ASS); (v) experiential knowledge (EK) and (vi) well developed general strategies (GS). This is epitomised and illustrated in Figure 1.

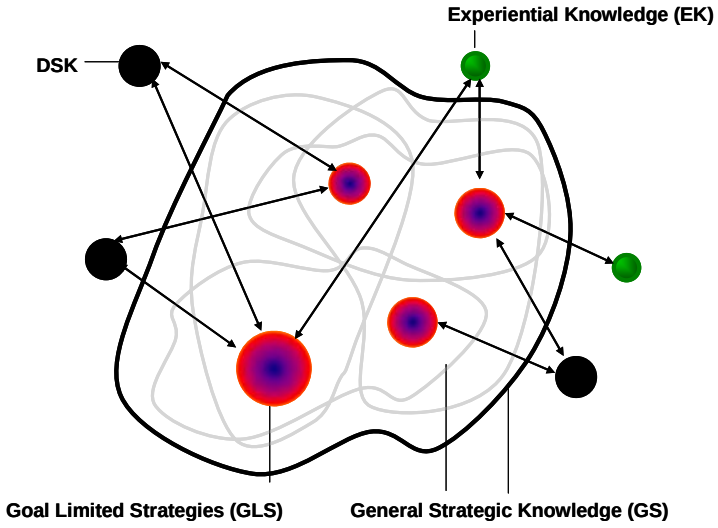

Fig. 1 Product-centred Knowledge Connection Model – Expert (Popovic 2002)

The descriptive model of product-centred knowledge connections operates on two levels (i) the *design product level* (early stage of the design process) representing design constraints grouped

in large “chunks”, goal-limited strategies (GLS) and generals strategie (GS); and (ii) the *knowledge level* representing relevant domain-specific knowledge (DSK) and experiential knowledge (EK) to connect with goal-limited strategies (GLS) to accomplish satisfactory outcomes.

The changing market environment (Section 1), and emerged areas of design (Table 1) require better understanding of people, as they operate at different levels of human engagement; this has become one of the major design concerns. This also indicates that more research is needed in order to understand people’s experiences and interactions. This poses the question of what design knowledge is required. The studies of expertise show that detailed domain-specific knowledge is necessary to solve problems successfully. To relate this to product design, a designer needs to understand the activity itself and the context in which products/ systems exist. The rationale of earlier research concentrated on the visuals: the most common media that designers use to interpret and reformulate design concepts. And the research demonstrates that they convey strategies and knowledge representation across and within the design domains (Horn 1998, Bucciarelli 2002, Oxman 2002, Popovic 2004). However, the new design areas emerging from the study of industrial design professional practices (Table 1) require new knowledge to assist designers to understand various levels of human engagement and interaction.

6. THE NEW ACTIVITY-CENTRED MODEL

Activity-centred interaction and design require understanding of the social context in which human engagement occurs at a group or individual level. It also requires the knowledge of cultures and sub-cultures of activities. The activity engagement requires an in depth understanding. How do activity and interaction occur within the different cultural contexts? These knowledge sources reside in activities and their actors. Therefore, the new knowledge model positions artifacts into the social context consisting of *people, activity, context and culture.* These are the main sources from which to draw the new knowledge (Fig. 2).

The descriptive model of activity-centred knowledge connection operates on three levels (i) the *design product level* (early stage of the design process) representing design constraints grouped in large “chunks” and goal-limited strategies (GLS) and general strategie (GS); (ii) *knowledge level* representing relevant domain-specific knowledge (DSK) and experiential knowledge (EK) to connect with goal-limited strategies (GLS) to accomplish satisfactory tasks and (iii) the level that deals with *knowledge about human engagement,* representing knowledge about *people, activity,*

context and culture. When identified, this knowledge is integrated with the domain-specific knowledge (DSK) and experiential knowledge (EK) relevant to the accomplishment of the design task.

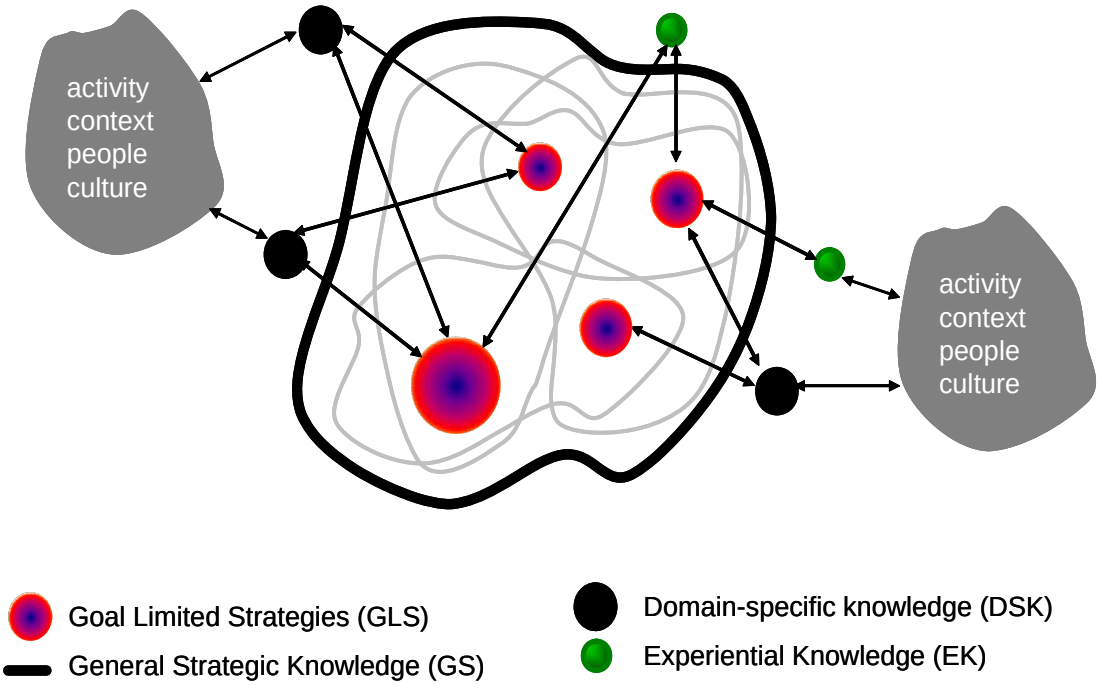

Fig. 2 Activity-centred Knowledge Connection Model – Expert

The earlier models inferred were based on the study of designer's visuals. In order to maintain consistency with the earlier studies, the same coded visuals are analysed for identification of activity representation in them. The coding process of expert designers' visuals reported elsewhere (Popovic 2004), has identified 377 goal-limited strategies (GLS) across all projects consisting of large and variable "chunks". It has been noted that representations of activities have not been included in the visuals. The indication is that there is no link, at this stage, between artifacts, activities and experiences and how they connect with domain-specific knowledge during the early stage of design. What is the activity-centred -knowledge and its representation in the design process? Its connections with relevant domain knowledge are yet to be defined. It is envisaged that one of the possible ways is by situating artifact research into the social structure (people, activity, context and culture) where artifacts are the mediators of knowledge generation and application.

7. CONCLUSION AND FUTURE WORK

This paper focuses on the activity-centred approach and identifies new product design knowledge necessary for this approach. It clarifies the emergent product design knowledge and presents descriptive, activity-centred and product-centred knowledge connection models. The significance of the integration of knowledge about activities into an artifact design, and an understanding of people's daily engagement is emphasised. The models presented are based on the study of representations of knowledge from visual data at the expert level. Visual data are used as they are the language of design which designers use to represent their knowledge and thoughts during the product design/ concept generation process.

The main strength of the current work is in describing and distinguishing two models – 'product-centred' and 'activity-centred'. These models have opened an avenue for better understanding of the importance of interaction among general strategies (GS), goal-limited strategies (GLS), domain-specific knowledge (DSK), experiential knowledge (EK) and social context (consisting of *people, activity, context and culture).* The 'product-centred' model operates on two levels (product/ system and knowledge levels), while the 'activity-centred' model operates on three levels (product/ system, knowledge and human engagement levels).

The activity-centred model described in this paper is the first attempt to determine directions for the future research needed to identify *knowledge about human engagement* and design - relevant knowledge about *people, activity, context and culture.* The main challenge for future work is to identify and integrate this knowledge with domain-specific knowledge (DSK) and experiential knowledge (EK) relevant to the accomplishment of the design task.

The presented models are developed within the product design domain but are transferable to other design domains as well. When developed fully, the activity-centred model might well have implications for design education (curriculum development) and practice (knowledge about human engagement utilisation). Finally, the models also provide the potential foundation for future design tool development.

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