Expert and Novice Users Models and their Application to the Design Process

Vesna POPOVIC

Queensland University of Technology, School of Design and Built Environment, GPO Box 2434 Brisbane 4001, AUSTRALIA, v.popovic@qut.edu.au

Abstract: This research was undertaken to provide the designers of interactive artifacts with more knowledge about the human users of these artifacts, and a better understanding of how they use them. Therefore the research explored differences and similarities between novice and expert users of interactive artifacts. In order to achieve this, protocol analysis was used to identify users' cognitive categories, knowledge categories and knowledge representation. Based on the taxonomy proposed and differences identified, each cognitive category was modelled. The models are designed on the premises that knowledge — domain-specific knowledge in particular — plays a significant role in distinguishing a novice from an expert user, and the way in which they use technologically interactive devices. They also constitute the features that reflect the kind of processes, representations, strategies or knowledge organisation that may occur for each cognitive category during the interaction. The models contribute to the better understanding of the differences between the novice and expert users while they interact with artifacts. Their potential applications are: (a) as designers' computer support tool to understand better the users of the artifact they design; (b) in design research in order to get better understanding how designers work; (c) for artifact useability assessment; (d) in education and design education in particular and (d) for different training procedures. This paper will explore the model applications to the design process. It will attempt to clarify how) the users' model should be included in the design process.

Key words: *expertise, modelling, design process, design cognition, interaction design*

1. Introduction

This research was undertaken to provide the designers of interactive artifacts with more knowledge about the human users of these artifacts, and a better understanding of how they use them. It is difficult to imagine users' behaviours, their concepts and the misunderstandings they have of interactive artifacts or systems; such understanding requires knowledge of the users' cognitive characteristics. The original research therefore explored differences and similarities between novice and expert users of interactive artifacts [1]. In order to achieve this, protocol analysis was used to identify users' cognitive categories, knowledge categories and knowledge representation. Protocol findings were analysed comparatively and significant differences were identified. This led to the development of a model taxonomy and user models.

The development of users' cognitive categories, knowledge categories and knowledge representation emerged from the users' protocols while they interacted with interactive artifacts in their contextual environment. These were analysed in relation with the relevant knowledge category and knowledge representation. The differences between expert and novice users were compared and identified with associated knowledge and knowledge representation for each cognitive category. They were identified by examining behaviour, mean and intensity of occurrence of protocol categories, knowledge categories and knowledge representation. As a result of these the following cognitive categories were identified [1, 2]:

- transition (0) - Transition between thoughts or a changing point to a new thought or as a change from one task to another or between protocol categories.
- goal (1) - What person wants to achieve.
- intention (2) - Decision to act to achieve goals.
- action (3) - A set of operational principles that represents knowledge behind the task.
- knowledge acquisition (4) - Learning process during which knowledge is acquired.
- user's concept (5) - Person's interpretation of an artifact or some of its function based on their conceptual knowledge.
- uncertainty (6) - Assumption about the process that generates information.
- search (7) - Person's queries and search for different aspects of knowledge in order to perform the required task.
- understanding (8) - Understanding of a procedure or principle behind the task or artifact.
- task (9) - Action paths that consist of action segments.
- evaluation (10) - Person's confirmation or verification of tasks, operational procedures or strategies.
- error (11) - Person's failures, contradictions or conflicts.
- planning (12) - Person's intermediate constructions to explore sequences of possibilities mentally.

The cognitive categories related knowledge and knowledge representations were developed during the protocol interpretation and its coding process. They are the following:

- declarative knowledge (Kd) - Knowledge of factual information - knowing what.
- procedural knowledge (Kp) - Compilation of declarative knowledge into functional units - chunks that incorporate domain-specific strategies - knowing how.
- strategic knowledge (Ks) - Knowledge and strategies that are used during the acquisition or utilisation of knowledge.
- situational (conditional) knowledge (Kc) - Conditional knowledge refers to understanding where and when to access particular facts or employ particular procedures.
- principled knowledge (Kpr) - Knowledge about a principle behind a task or artifact function.
- instruction manual (Mk) - Knowledge acquisition from an artifact instruction manual.
- interface knowledge (Ki) - Person's knowledge about an interface layout.
- task knowledge (Kt) - Person's knowledge about a required task.
- knowledge misunderstanding (Km) - Person's misunderstanding of knowledge.

Based on the taxonomy proposed and differences identified, each cognitive category was modelled. The models are designed on the premises that knowledge — domain-specific knowledge in particular — plays a significant role in distinguishing a novice from an expert user, and the way in which they use technologically interactive devices [1]. They also constitute the features that reflect the kind of processes, representations, strategies or knowledge organisation that may occur for each cognitive category during the interaction. These features differentiate novices from experts as they show the differences in processes that occurred for each cognitive category.

2. Expert and Novice Users Models

These models (Figures 1 and 2) are based on think-aloud (TA) protocol data that resulted from the interpretation of protocol coding [1, 2]. Protocols provide ideas about how to model the cognitive processes of user's behaviour. The model taxonomy was generated after differences were identified and justified. The taxonomy emerged from the analysis and interpretation of protocol data which were summarised for each category. For example, cognitive category *search* shows that experts have Domain Knowledge (DK), Superior Memory Recall (SMR) and Task Experience and Expertise (TE); novices do not have Domain Knowledge (DK) or Task Experience and Expertise (TE); novices search for domain-specific knowledge in the Instruction Manual (Mk); novices have Weak Memory Recall (WMR). This approach is applied consistently for each protocol and knowledge category and knowledge representation [1]. These identified differences are seen to be the main features of the models and will be discussed further in this paper. Each model consists of (a) permanent features, (b) expert features and (c) novice features.

2.1 Permanent Model Features

Permanent features of the model emerged from the research and relevant theoretical foundations about human expertise which support the significance of the knowledge levels that artifact users must have in order to be able to perform tasks. This significance becomes more apparent in the case of interactive artifacts [1]. The permanent features for both novice and expert models are:

- *General Knowledge (GK).* This comprises declarative and procedural knowledge and is represented as strategic or situational (conditional) knowledge. It is the knowledge derived from general learning and experience which is represented as general strategic or situational knowledge [3, 4]. Without this knowledge it will not be possible for a novice to acquire domain-specific knowledge and develop to become an expert.
- *Domain Knowledge (DK)* or domain-specific knowledge is knowledge in the particular field of expertise. Relevant research shows that successful performance depends on the content and structure of this particular knowledge [1]. General and domain-specific strategies are required to monitor this knowledge. In order to be able to develop into an expert, a novice should have a certain amount of domain knowledge, which allows the use of strategic knowledge in the domain tasks. This means that learners should posses some relevant knowledge of that domain [5]. In the case of novice users, this is accomplished by using an instruction manual. Domain knowledge content is important for the transitional process from novice to expert.

- *Task Domain (TD)* refers to the task that users are to perform and to which they must apply domain-specific knowledge and procedures. It can be a well-defined or ill-defined task or problem to be solved, and requires knowledge distinct from that of the particular expertise.
- *Transition (T)* is a changing point, when users make changes between their thoughts, or protocol categories or knowledge categories. It occurs in the particular problem space in which the processing occurs. Therefore, it acts as a processor.
- *Task Execution (TEX)* is a task or sub-task completion outcome.

2.3 Representation of Models

Both expert and novice models are represented in the form of diagrams. There are permanent features common to both models, but their overall content remains variable. In the model diagrams (Figures 1 and 2), expert and novice features are placed around each model's permanent components respectively. All components in the model are linked. A transition operates as a processor between particular components when they are active. It is activated at the time when the change occurs between the users' thoughts or between the model's units or cognitive categories. Protocol categories, knowledge categories and knowledge representation which are the result of these research findings are cognitive categories that generate the users' activities relevant to the task performance. They will be modelled in order to show the differences between expert and novice artifact users. The distinction between the categories is conceptual rather than physical. Figures 1 and 2 show the general configurations of the expert and novice models respectively. They are process models based on novice and expert user differences [1]. As indicated, the features that constitute and differentiate the models are arranged around the permanent model components. The links between the features are representations of all links, as generated by each category modelled.

Figures 1 and 2 are graphic representations of the models. The rationale for these diagrams is based on the model design objectives. These are (a) development of a model taxonomy relevant to both expert and novice users, (b) identification of permanent interdependent features of the model and (c) identification of the content of permanent model components. The identification of permanent, interdependent features of the model that emerged from the research [1] illustrate the significance of the knowledge levels that artifact users must have in order to be able to perform their tasks. The main significant feature in this configuration is the knowledge component, represented by a large rectangular shaded shape (Figures 1 and 2). It consists of *General Knowledge (GK)* and *Domain Knowledge (DK)* and differs between expert and novice users. The second permanent feature is *Task Domain (TD),* represented by a shaded circle. This refers to the task that users are to perform and to which they must apply domain-specific knowledge and procedures. The third permanent feature is *Task Execution (TEX),* represented by a shaded square. refers to a task or sub-task completion outcome. The last permanent feature is *Transition (T),* represented by a small square. It is a changing point where users make changes between the thoughts or protocol categories, and acts as a processor. In figures 1 and 2, expert and novice features are placed around each model's permanent components respectively. They are distinguished graphically as squares and rectangles (expert), and rounded rectangles and squares (novice). All components of the models are linked, transitions operating between particular components when they are activated.

Figure 1 shows the expert-user model configuration in generic terms. It consists of (a) permanent model features, (b) expert domain and general knowledge features and (c) expert model features. As permanent model features are discussed in the previous paragraph, only expert domain and general knowledge content will be outlined here. General knowledge features are common for both categories of users—expert and novice. This is the knowledge derived from general learning and experience [3, 4]. This knowledge comprises *Declarative Knowledge (Kd), Situational Knowledge (Kc), Strategic Knowledge (Ks)* and *Procedural Knowledge (Kp).* These are represented as small rectangles in the knowledge component of the diagram and are identified by appropriate abbreviations. Expert domain-specific knowledge features represent the knowledge in the particular area of expertise. They are represented as large rectangles in the knowledge component of the diagram and are identified by an appropriate abbreviation. They are: *Domain-Specific Situational Knowledge (DSKc), Domain-Specific Strategic Knowledge (DSKs), Domain-Specific Declarative Knowledge (DSKd), Domain-Specific Procedural Knowledge (DSKp), Interface Knowledge (Ki), Principled Knowledge (Kpr),* and *Task Knowledge (Kt).*

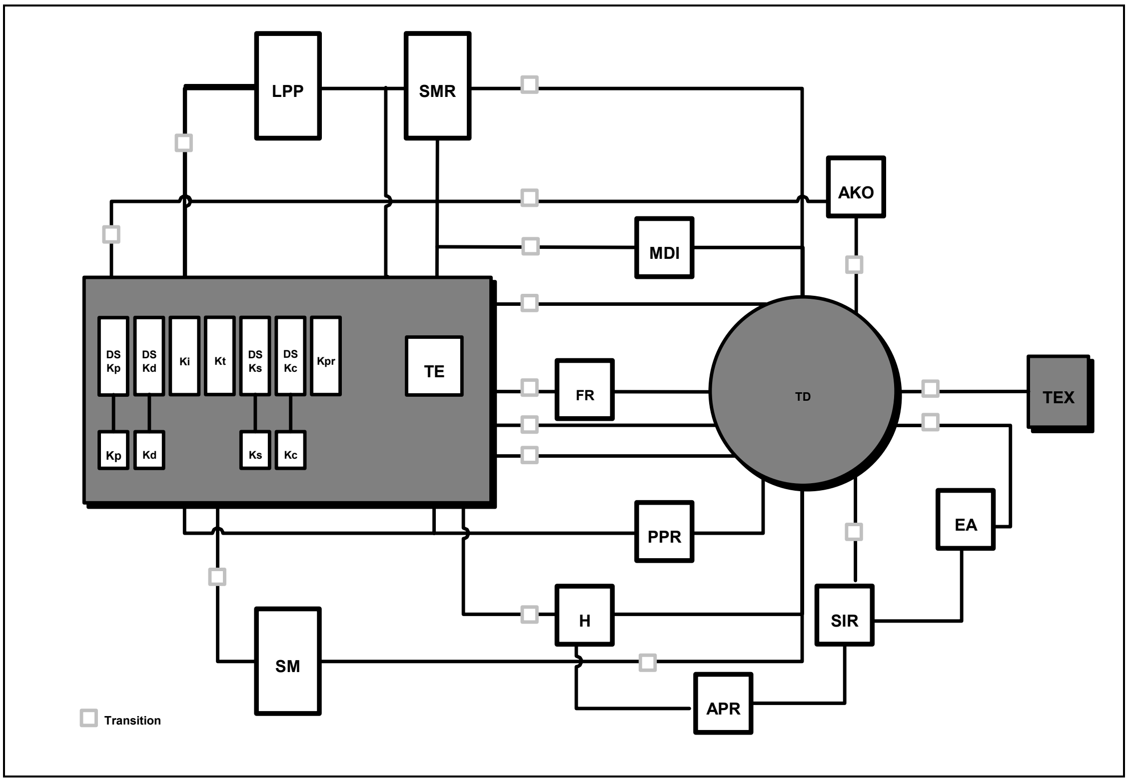

Figure 1. Expert Model

Expert model features are the elements of the model's taxonomy and represent characteristics of experts that provide them with a superior performance in many situations. They are: *Abstract Knowledge Organisation (AKO), Abstract Problem Representation (APR), Error Awareness (EA), Forward Reasoning (FR), Heuristics (H), Large Pattern Perception (LPP), Multi-Domain Inference (MDI), Problem Information Inference (PII), Principled Level Problem Representation (PPR), Stable Internal Representation (SIR), Skilled Memory (SM), Superior Memory Recall (SMR)* and *Task Experience and Expertise (TE).* All these components are placed around the permanent model features with the exception of *Task Experience and Expertise (TE)* which is included in knowledge, as domain experts have knowledge that comes from their experience in that particular area of expertise. All these components are connected by *Transition (T)* which acts as a processor when an appropriate cognitive category is active.

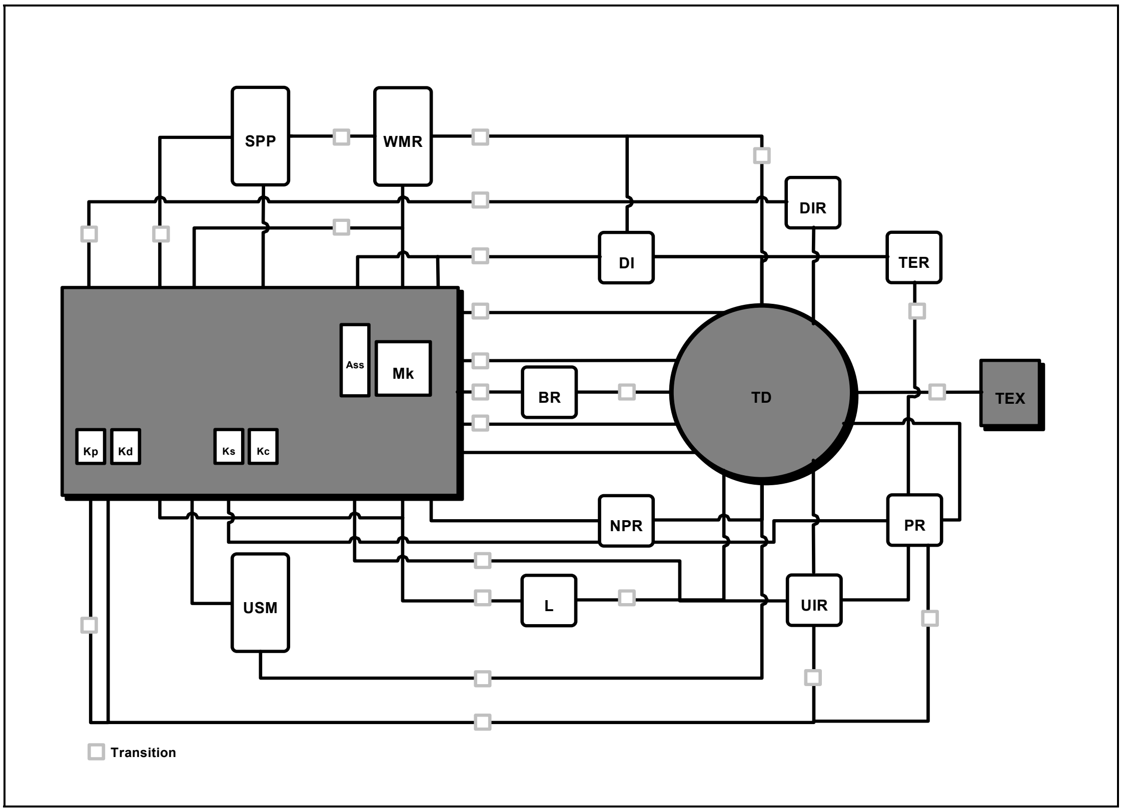

Figure 2. Novice Model

Figure 2 shows the novice-user model configuration in generic terms. It consists of (a) permanent model features (b) novice model knowledge features and (c) novice model features. Permanent model features are discussed in a previous paragraph. Therefore, only novice knowledge features will be outlined here. These are general knowledge components that are common for both categories of users—expert and novice. This is the knowledge derived from general learning and experience [3, 4]. Without this knowledge it would not be possible for a novice to develop and become an expert. This knowledge comprises *Declarative Knowledge (Kd), Situational Knowledge (Kc), Strategic Knowledge (Ks)* and *Procedural Knowledge (Kp).* These are represented as small rectangles in the knowledge component of the diagram and are identified by appropriate abbreviations. They are common for both users, except that for experts, they are linked with the domain–specific knowledge relevant to a particular task.

The elements of the model's taxonomy represent novices' features that represent novices' characteristics. They are: *Assumption (ASS), Backward Reasoning (BR), Domain Independent Representation (DIR), Domain Inference (DI), Learning (L), Instruction Manual (Mk), Naive Problem Representation (NPR), Problem Restructuring (PR), Small Pattern Perception (SPP), Trial-and-Error (TER), Unstable Internal Representation (UIR), Unskilled Memory (USM)* and *Weak Memory Recall (WMR).* All these components are placed around the permanent model features with the exception of *Assumption (ASS)* and *Instruction Manual (Mk),* which are included in knowledge, as novices do not have domain-specific knowledge and either make assumptions while trying to perform the task, or use the instruction manual to acquire domain-specific knowledge. All these components are connected by *Transition (T)* which acts as a processor when an appropriate cognitive category is active.

The diagrammatic representations of the models (Figures 1 and 2) are based on the rationale of showing the differences between the models by using a graphic layout that will allow the observer to see the transition process from novice to expert. This is achieved by placing, in most instances, the model's features that are opposite in their characteristics at the same position in both layouts. During the process of knowledge acquisition and task experience, the knowledge of novices will develop, as they will acquire, gradually, domain-specific knowledge in addition to the general knowledge they already have. Therefore, *Procedural Knowledge (Kp)* will expand to contain *Domain-Specific Procedural Knowledge (DSKp), Declarative Knowledge (Kd)* will expand to contain *Domain–Specific Declarative Knowledge (DSKd), Strategic Knowledge (Ks)* will expand to contain *Domain–Strategic Knowledge (DSKs)* and *Situational Knowledge (Kc)* will expand to contain *Domain-Specific Situational Knowledge (DSKc); Assumption (ASS*) and *Instruction Manual (Mk)* will be replaced with *Task Experience and Expertise (TE).* The expert will develop *Interface Knowledge (Ki), Task Knowledge (Kt)* and *Principled Knowledge (Kpr)* relevant to the particular artifact interface.

During the transition, the features of the models will change gradually as follows: *Backward Reasoning (BR)* will become *Forward Reasoning (FR); Domain Independent Representation (DIR)* will become *Abstract Knowledge Organisation (AKO)* and *Abstract Problem Representation (APR); Domain Inference (DI)* will become *Multi-Domain Inference (MDI); Learning (L)* will become *Heuristics (H); Naive Problem Representation (NPR)* will become *Principled Level Problem Representation (PPR); Problem Restructuring (PR)* and *Unstable Internal Representation (UIR)* will develop into *Stable Internal Representation (SIR)*; *Small Pattern Perception (SPP)* will develop into *Large Pattern Perception (LPP); Trial-and-Error (TER*) will develop into *Error Awareness (EA); Unskilled Memory(USM)* will develop into *Skilled Memory (SM),* and *Weak Memory Recall (WMR)* will develop into *Superior Memory Recall (SMR).*

The above was the rational for the graphic representation of the model diagrams. It may be possible that different graphics of the models could be developed. However, with the rationale presented, these very structured graphs seem to be the most appropriate to illustrate the differences between expert and novice users of interactive artifacts.

It is envisaged that the proposed models operate in all relevant stages of users' activities [6] where an appropriate cognitive category (or categories) will be used by novice and expert users during interaction with artifacts in their contextual environment of use. This research assumes that the knowledge is represented and structured in schemas — representational systems in the category of propositional representation [7]. The use of knowledge structure is dependent on users' mental models [8]. The theory assumes that mental models can be constructed on the basis of verbal or perceptual information. The images correspond to the model components that are "directly perceptible" in the real world. The proposed models are based on the use of interactive artifacts where an interpretation and artifact concept depend on a user's perception of an interface layout. This plays an important role in understanding the concept behind an artifact's design. Therefore, mental models theory seems to be relevant to adopt for the use of the knowledge structure for each relevant cognitive category modelled. Consequently, the models are based on the premise that they contain elements of both "a combination of the mental models and pragmatic schema approaches" [9].

3. Application of the Model to an Artifact Design

The main purpose of this research is to assist the designers of interactive artifacts to understand better artifact users for whom they design by understanding what kind of knowledge they may need in order to achieve a successful interaction. As stated earlier it is envisaged that the proposed models operate in all relevant stages of users' activities [6] where an appropriate cognitive category (or categories) will be used by novice and expert users during the interaction. The models can be applied through all the stages of the design process, from the early stage to the interaction testing of the finished artifacts. The application of the model is discussed with reference to two cognitive categories – *intention* (Figures 3 and 4) and *interface knowledge* (Figures 5 and 6). They are used as characteristic examples.

Figure 3 shows that an expert user has an intention to achieve a goal and employs domain-specific knowledge. As the intention is defined as a decision to achieve the goal, its characteristic is demonstrated by the experts' stability of their internal representation. They are able to decide what is the most appropriate representation required. The arrow indicates the category flow. The model illustrates that expert users make transitions from knowledge — General Knowledge (GK) and Domain-Knowledge (DK) to Task Domain (TD), then a transition toward an internal representation which is stable (SIR) and a transition to knowledge. The model demonstrates that expert users decide what is the most appropriate representation required by making stable internal representations of the task and applying relevant domain-specific knowledge.

Figure 4 shows that novice users employ general knowledge. They are not able to decide what is the most appropriate representation required as their internal representation is unstable and has changed often during the task. The model shows that novice users make transitions from the Task Domain (TD) to General Knowledge (GK); then a transition toward an internal representation which is unstable (UIR) and a transition to the Task Domain (TD). As the novice users employ general knowledge, their internal representation shifts very often as they have difficulty deciding which representation is the best to solve the problem. They may attempt to make several different decisions, going through the same procedures until they make the right decision.

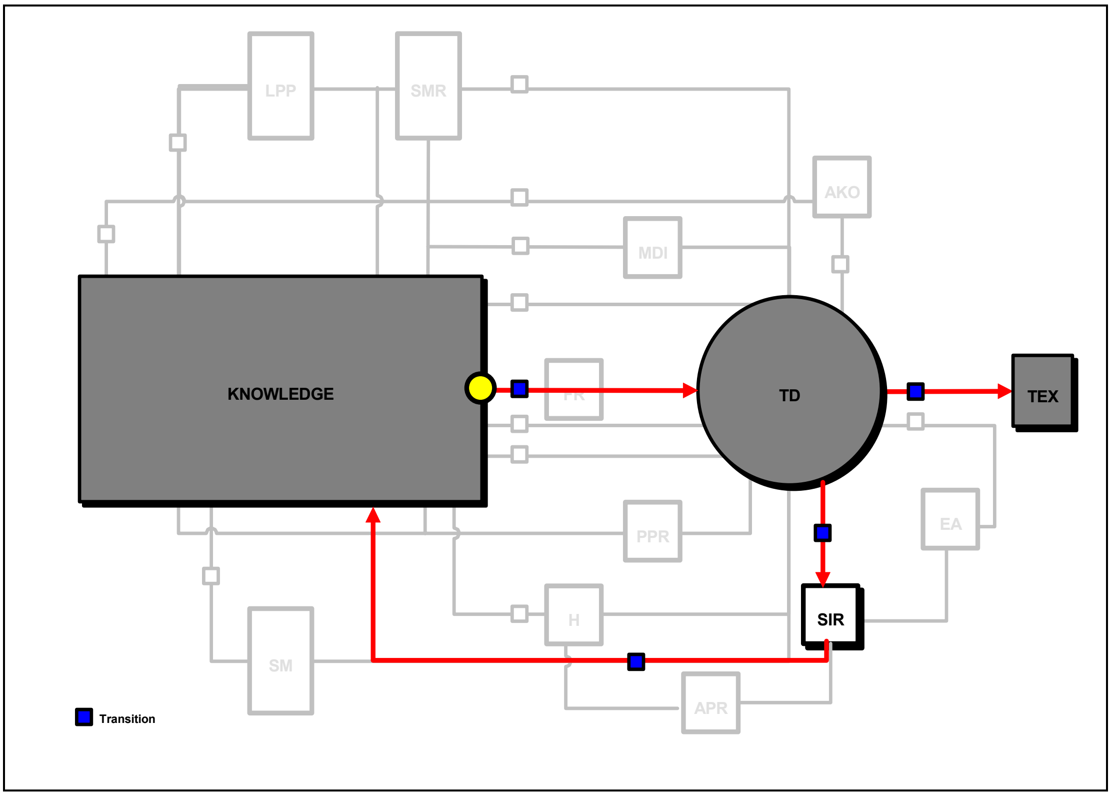

Figure 3. Cognitive Category Intention Model – Expert

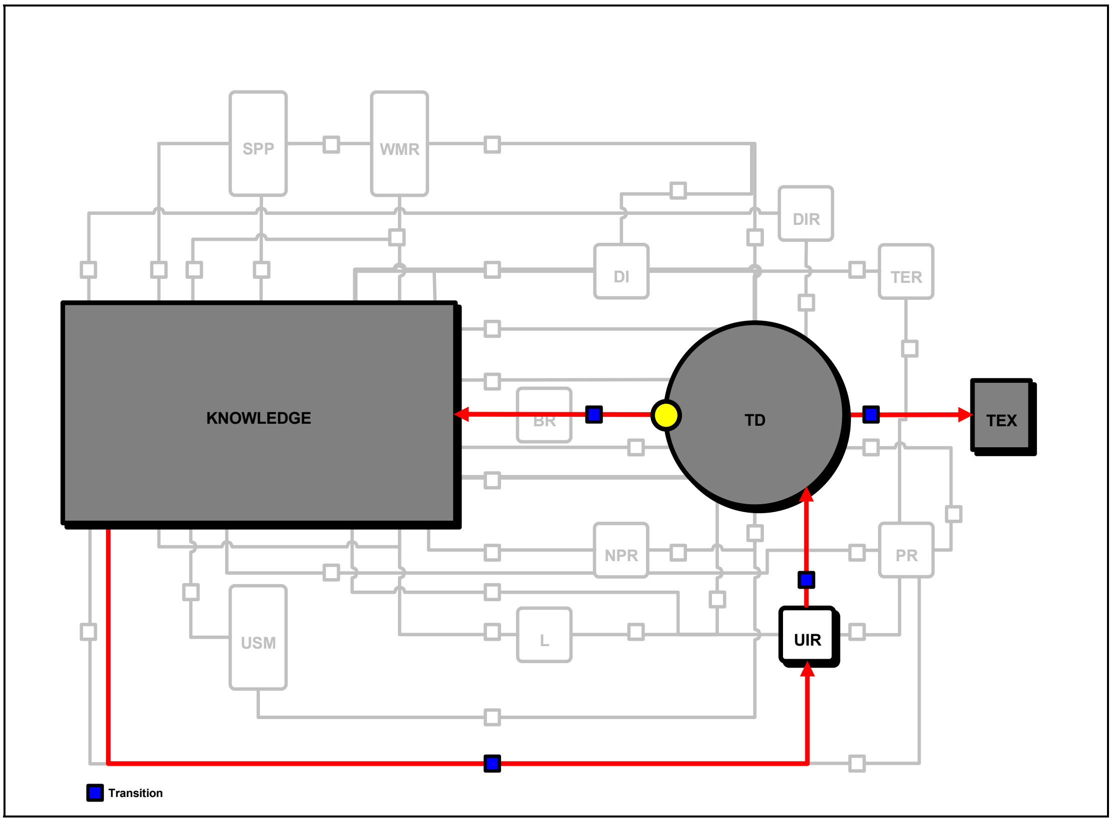

Figure 4. Cognitive Category Intention Model – Novice

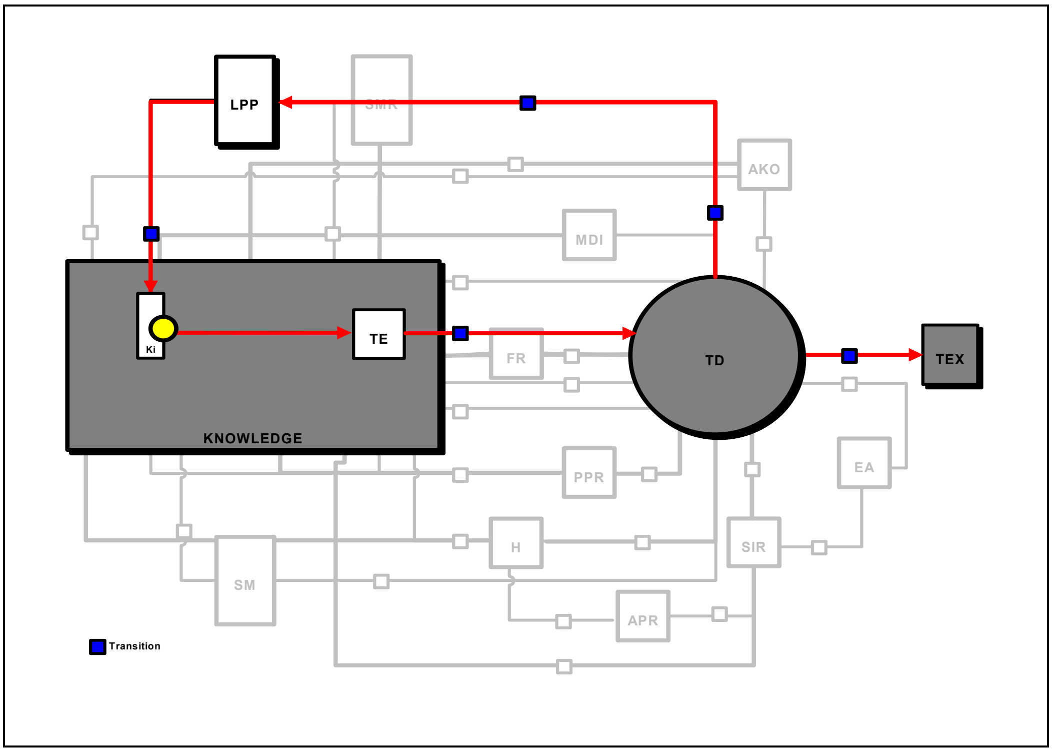

Figure 5. Knowledge Category Interface Knowledge Model — Expert

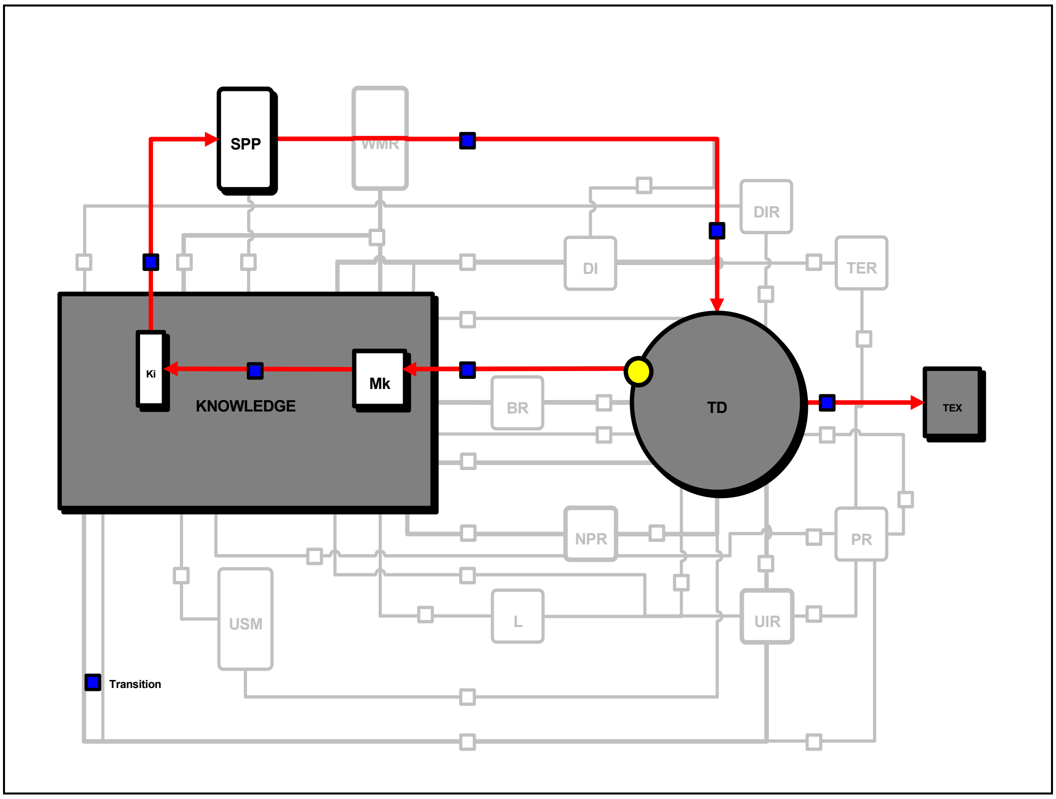

Figure 6. Knowledge Category Interface Knowledge Model — Novice

Figure 5 shows the way the expert users employ interface knowledge (Ki). They posses domain-specific interface knowledge and expertise, and they perceive large meaningful patterns. The model shows that expert users make transitions from knowledge — Domain-Specific Interface Knowledge (Ki) to Task Experience and Expertise (TE) then Task Domain (TD); then a transition toward Large Patterns Perception (LPP) and a transition to Domain-Specific Interface Knowledge (Ki) and Task Experience and Expertise (TE). The model demonstrates that expert users have knowledge about the interface layout.

Figure 6 shows that novice users do not have domain-specific interface knowledge and refer to the instruction manual. They also perceive small interface patterns. The model shows that novice users make transitions from Task Domain (TD) to General Knowledge (GK) and Instruction Manual (Mk); then to Interface Knowledge (Ki) and from there a transition to Small Pattern Perception (SPP) and to Task Domain (TD) again.

One of the most important issues for designers to consider is how to facilitate the novice – expert transitional process and design artifacts and their interfaces that would support this evolution. For example, the design should facilitate novices to quickly acquire domain-specific knowledge in order to support their transition from *Unstable Internal Representation (UIR)* to *Stable Internal Representation (SIR)* (Figures 3 and 4) or from *Small Patterns Perception (SPP)* to *Large Patterns Perception (LPP)* (Figures 5 and 6). The key element for an artifact design is to identify which novice – expert cognitive characteristics of the model are relevant for that particular design and integrate them into the design constraints. The model can assist designers to determine what is the minimum domain-specific knowledge required by novice users in order to achieve interaction with an artifact and acquire an adequate expertise. However, it is important to note that, across a wide range of activities, the improvement of human interaction is in direct relation to the amount of practice that is done. It is possible for human users to decrease their skill acquisition in a wide range of tasks and domains on the basis of experience. Experience plays an important role in problem solving [10, 11]. This research illustrates 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" [11].

Alexander and Judy [12] revealed differences between the knowledge structures and problem solving procedures of novices and experts. This is supported by the idea that a suitable, organised cognitive structure plays a significant role in retrieving and encoding knowledge relevant to problem solving. It was also argued by Chase and Simon [13] that the main differences among novices, experts and masters in different domains were related to their immediate access to relevant knowledge. Therefore, the designers should determine which information will be required. The design should facilitate their rapid retrieval and perception in order to support utilisation of a minimal conscious cognition and an intuitive interaction [14].

4. Conclusion

This research is seeks to provide artifacts designers with more knowledge about the human users of interactive artifacts that they design. The research underlined the cognitive structure behind novice and expert users models that emerged from the protocol analysis of experts and novices interaction. It is envisaged that novice and expert differences, as demonstrated by the research will contribute to the better understanding of human interaction with the artifacts. The author believes that application of the models during the design process will facilitate better understanding of which cognitive structure might be appropriate and what is the minimal knowledge required to achieve an intuitive interaction. The application of the models might have implications for the design of products and interactive artifacts, as designers might make use of them to predict/assess users' interaction.

References

1. Popovic V. Novice and Expert User Models, PhD dissertation, University of Sydney, Sydney (1998).
2. Popovic V. Expert and Novice User Differences and Implications for Product Design and Useability, Proceedings of the IEA 2000/HFES 2000 Congress, San Diego, 933-936 (2000).
3. Ericsson KA, Smith J. Prospects and Limits of the Empirical Study of Expertise an Introduction. In Ericsson KA, Smith J (Eds). Toward a General Theory of Expertise, Cambridge University Press, New York, 1-38 (1991).
4. Christiaans H. Creativity in Design, LEMMA Publishers, Utrecht (1992).
5. Smith MU, Good R. Problem Solving and Classical Genetics – Successful versus Unsuccessful Performance, Journal in Research in Science and Teaching, 21, 895-912 (1984).
6. Norman DA. Cognitive Engineering. In: Norman D, Draper S (Eds). User Centred System Design, Lawrence Erlbaum, Hillsdale, 32-61(1996).
7. Rumelhart DE, Norman DA. Representation of Knowledge. In: Aitkenhead AM, Slack JM. (Eds). Issues in Cognitive Modeling, Lawrence Erlbaum, Hillsdale, 14-62(1985).
8. Johnson-Laird PN. Mental Models, Cambridge University Press, Cambridge (1983).
9. Koedinger KR, Anderson JR. Abstract Planning and Perceptual Chunks: Elements of Expertise in Geometry, Cognitive Science, 14, 511-550 (1990).
10. Visser W. Use of Episodic Knowledge and Information in Design Problem Solving. In: Cross N, Christiaans H, Dorst K (Eds) Analysing Design Activity, John Wiley and Sons, Chichester, 271-289 (1996).
11. Kolodner JL, Simpson RL. Problem Solving and Dynamic Memory. In: Kolodner JL, Riesbeck CK (Eds). Experience Memory and Reasoning, Lawrence Erlbaum, Hillsdale, 99-144 (1986).
12. Alexander PA, Judy, JE. The Interaction of Domain-specific Knowledge, Academic performance, Review of Educational Research, 4, 375-4004 (1988)
13. Chase WG, Simon, HA. Perception in Chess, Cognitive Psychology 4, 55-81 (1973).
14. Blackler A, Popovic V, Mahar, D. Intuitive Use of Products. In: Durling D, Shackleton J (Eds), Common Ground Proceedings, Staffordshire University Press, Staffordshire, 120-135 (2002).