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CLASSIFICATION OF USERS IN THE CONTEXT OF KNOWLEDGE TRANSFER IN PRODUCT DEVELOPMENT

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1. Introduction

"Knowledge is power". Extensive, consolidated knowledge is essential for high-level problem-solving abilities in all fields. As a result, profound knowlegde can be regarded as a prerequisite for excellent performance [Holyoak 1991]. In contrast to reasoning and problem-solving, which can be trained just to a certain degree, the aquisition of knowledge as a basis for those abilities can be supported in many ways [Weinert 1997].

Product development is an integrating function, which requires a broad spectrum of knowledge. In this work the expression *knowledge* is used in the sense of domain-specific knowledge. In this context, domain-specific knowledge contains terms, definitions, relationships and typical problem-solving methods of the regarded domain. That means in particular design theory, design methods and solutions. As there is a great variety of different target groups that are trained in product development (e.g. students, industrial designers), the process of knowledge transfer has to consider their specific requirements regarding the preparation and presentation of contents. Furthermore, different user scenarios of knowledge transfer have to be considered. In pricipal, these contents can refer to the same knowledge base, but have to be presented in quite different ways. Using a single knowledge base for different user types in different training scenarios could help to reduce efforts, as contents have to be generated only once.

In this context the ***pinn****gate* project was initiated. It is to the successor of the *thekey*-approach [Albers et al. 2001][Birkhofer et al. 2002]. The objective of ***pinn****gate* is to develop a holistic teaching, learning, and application system, which is able to manage large amounts of knowledge – primarily in the range of product development. The system has to support different user types in both academic and industrial environments by using just one, flexible, modular, high-quality content base. For that reason, individual documents considering user type and user scenario have to be created.

To obtain the required flexibility in regard to document configuration, contents are modularised by a 3-level-model. This so-called EMC-model is mainly based on text and picture fragments (**E**lements on level 1), which are combined in explanations, examples, chapters etc. (**M**odules on level 2, **C**ontainers on level 3) [Berger 2004]. Document configuration implies all aspects concerning structure, layout, quantity and quality of contents, as well as didactical aspects.

The focus of this paper refers to the different user groups, that can be supported by an integrated learning, teaching and application system. Individual user requirements are essential for the configuration process and the structure of the later documents. Besides, consolidated findings on user requirements could necessitate enhancements of the described modularisation approach. To provide a basis for further research on user requirements, this work will introduce a user classification for the system described above. This classification is based upon a general scale of expertise with regard to the special context of product development. In addition, it will consider both academic and industrial environments.

2. State of Research

During the mid- and late 1960s, artificial intelligence and cognitive psychology started to become important fields of research. Accordingly research on expertise gained in importance.

To date, there are hardly any explicit, operational definitions of experts. In literature experts are usually defined by the choice of people that are examined. Hence, there is a great variety of different criteria chracterising experts [Gruber/Mandl 1996]. The probably most widely accepted, but also most general definition is made by Posner. According to his definition, an expert is a person with excellence in a specific domain. This excellent performance has to be perpetual, not temporary or just singular [Posner 1988]. As there should be some difficulties in defining a domain and in measuring expert performance, the definition of Krems, that contains more psychological criteria, should be more appropriate. According to his definition, expertise is the domain- or task-specific problem-solving ability, that always enables one to produce outstanding performance. In this context, an expert has a broad knowledge base, comprehensive experience in recognizing and solving problems and meta-cognitive control over operations. He works in an efficient way with high accuracy. In addition, he demonstrates great flexibility when confronted with unfamiliar problems [Gruber/Mandl 1996].

In contrast, a novice is described as a person, who is not at all familiar with the domain. He has no relevant knowledge or experience. It is remarkable that domain-specific knowledge plays a decisive role in almost all definitions of expertise. For that reason, profound knowledge can be regarded as the most fundamental component of expertise.

Assuming that knowledge does not depend on genetic fundamentals - with the result that any person could become an expert in a certain domain - three different sources of knowledge can be identified: instruction, individual experience and creative, deductive reasoning [Rothe/Schindler 1996].

Concerning education in the context of product development, instruction is primarily confined to academic education. It is noteworthy that many students have competent knowledge of concepts, facts, procedures etc., but are not able to apply this knowledge in solving specific problems. Even though this knowledge is apparently available, it seems to be represented by an “inactive” structure [Rothe/Schindler 1996]. Potential implications on instruction methods are evident.

As individual (professional) experience is regarded to be one key factor for knowledge acquisition, it is linked to the acquisition of expertise in the same way. It can be assumed that, in general, it should take a period of at least 10 years to become an expert [Ericsson/Crutcher 1990]. Considering that product development is based much more on professional experience than other domains, the required period of time should be much longer. In this context, it is not just extensive, but systematic and intensive training, that is essential to succeed on the way to becoming an expert. Long-lasting training alone cannot be regarded as a sufficient condition for expertise. Creative deductive reasoning – the third base of knowledge acquisition – generates new knowledge from existing knowledge structures.

In cognitive psychology, changes in the internal organisation of knowledge are seen as an essential factor in the development of expertise. Furthermore, newly assimilated knowledge has to be integrated by cognitive processes in a systematic way. In conclusion, it not only depends on the quantity and quality of stored knowledge, but also on the way it is structured or represented. Research in cognitive psychology has resulted in three formalisms of knowledge representation that can be used to explain expertise at least to a certain extent: production systems, schemas and case-based structures.

Production systems can be regarded as automated collections of “if-then” rules. To date, they are widely accepted in the field of expertise research. They can be used to explain the way experts recognise patterns with regard to specific problems. In addition, they provide indications concerning the different strategies of experts and novices and help to explain learning processes. Anderson’s ACT-theory, for instance, describes the way a declarative representation of knowledge, which is typical for novices, is transformed into a procedural one, which characterises experts. The process of transformation is called *knowledge compilation*. Knowledge that is represented by a declarative structure (in particular factual knowledge) can be generated by classical processes of knowledge acquisition (e.g. study textbooks). Procedural knowledge is considered to be the result of compiled declarative knowledge.

Schema-based models of problem-solving contain three steps: (1) recognise a task and place it in a specific problem class, (2) activate an appropriate problem-solving method, (3) execute this method. Thus, it appears that a schema contains information about the regarded situation and the different ways of solving the problem. Scheme-based models are used to explain the fact that novices solve problems by coding characteristics of the present situation, whereas experts activate specific theoretical concepts [Reimann 1998].

On the surface it could seem that representations of cases can be compared with schema-based models. But unlike schemes, cases represent episodic, situative knowledge that is *not* used to support generic but specific problem-solving.

Reimann describes a model of expertise development that is based on these three representaion formalisms. According to this model the development can be divided into three states: The novice state is characterised by knowledge representaions, that are unspecific in regard to different applications, in particular, semantic networks or declarative rules. Problem-solving, which is based on this kind of knowledge, is slow, search-based and error-prone. It can be considered as knowledge, which is transfered from textbooks without any modification. With growing experience, knowledge structures are reorganised. They are adapted to specific tasks and constraints. Automatisms (e.g. production systems), in terms of Anderson's compiled knowledge structures, are developed. In addition, declarative knowledge structures (e.g. schemas) that represent typical constraints and solution methods are generated. Thus, problem-solving is not so much based on searches but rather on former experiences. In the last state, knowledge is broadened by experience from specific cases. A real expert is primarily defined by this kind of specific knowledge [Reimann 1998]. Regarding this model the importance of experience on the way to gaining expertise is evident.

In the range of medical expertise, Patel & Groen distinguish between generic and specific experise, what could be described as the differences between "know-what" and "know-how". Generic expertise is characterised by declarative knowledge structures, whereas specific expertise is characterised by procedural abilities. It is quite obvious that generic expertise should be a prerequisite for specific expertise. Within the development of expertise, Patel & Groen identify four different levels: novice, intermediate, subexpert and expert. The development from the first to the second level is similar to Anderson's ACT-theory as described above. The knowledge of a novice is primarily organised within causal, proportional networks. In contrast, intermediates have compiled those structures into a simplified network. Generic expertise of subexperts is characterised by the development of domain-specific schemes or scripts. On the level of experts, these structures are completed by case-based instance scripts [Patel/Groen 1991].

Another model, that also includes non-cognitive aspects of expertise, has been developed by Dreyfus & Dreyfus. It contains five levels of expertise. The model describes the development of expertise in a more general way, regarding different groups, like car-drivers, nurses, managers, chess players etc. The model points out that novices approach a problem from a distant perspective, following specific instructions, while the expert's approach is more intuitional. In regard to advanced beginners the model points out the more experience-based (not rule-based) identification of situational elements, as well as the competent use of plans and perspectives [Dreyfus/Dreyfus 1986].

Concerning the context of design Lawson and Dorst suggest a 7-level model, which ranges from naive to visionary [Lawson/Dorst 2005]. Expert designers seem to be 'ill-behaved' problem-solvers, especially in terms of the time and attention, they spend on defining the problem. They take the view that expert designers are solution-focused and not problem-focused. It seems to be a feature of design cognition that comes with education and experience in designing. In particular, experience in a specific problem domain enables designers to move quickly in identifying a problem frame and proposing a solution [Cross 2004].

3. Deficits & Research Question

In contrast to traditional research on expertise, it is assumed today that there is no need for exceptional talents to reach an expert level. As a result, any person could become an expert within a specific

domain [Gruber/Ziegler 1996]. In consideration of this fact, a user classification for an integrated learning, teaching and application system can be based on a model that represents the development to an expert level. The system has to support its users in an effective and efficient way regarding both their present situation and their development in reaching a higher level of expertise.
Former expert models of different domains (as described above) are based on a general scale of expertise. These models describe the development within just a single continuous context, starting with career entry and ending on a specific expert level. Concerning academic education, these models do not usually have different levels of student expertise. As these models mainly focus on professional experience, students are seen as an undifferentiated group, even though their abilities and knowlegde can differ quite a lot. It is quite obvious, that different requirements for instruction cannot be identified when all students are classified on the same level. In addition, within an integrated learning, teaching and application system, different environments have to be considered, as they should strongly influence user requirements. In conclusion, a classification model should be established that includes both a genaral scale of expertise and specific elements describing the situational context.

4. User Classification

In the field of product development tasks are usually non-linear, not completely clarified and dependent on a specific situational context. At the beginning of the problem-solving process, at least some constraints and determining factors are not yet identified. Simple representation formalisms like production systems may be suitable to explain motor abilities and routine works, but they will probably fail to explain problem-solving processes in product development. As a result, a classification model based on general expertise has to consider this special situation.
According to the object of the described system, an appropriate user classification includes three user environments (cf. Fig. 1): (1) a learning environment, (2) a teaching environment and (3) a designing (=application) environment. Every user is assigned to one of these environments. The system is represented as an external knowledge base. Arrows show the regarded directions of knowledge transfer.

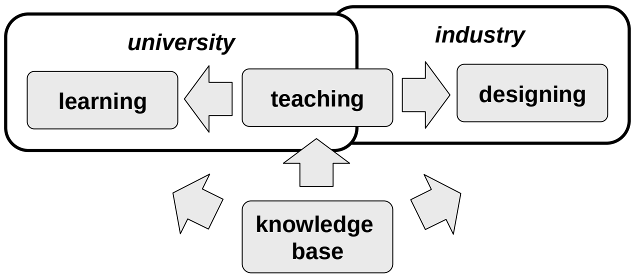

Figure 1. Knowledge transfer within user environments

As an integrated support system in product development is designed for both users at university and in industry, the three described environments can be assigned in a similar way. The teaching environment primarily belongs to university, while the designing environment, which includes professional designers, is assigned to the field of industry. In this context, it is assumed that the teaching environment has an integrating function between university and industry. It is primarily assigned to university, but intersects with the field of industry, as well. This intersection represents an interface of knowledge transfer considering academic cooperations with industrial companies. All potential users of the system can be assigned within this figure, except laymen who are not involved in the process of knowledge transfer.
The general knowledge sources (cf. section above) are integrated in the classification model, as they are fundamental for the process of knowledge acquistion and as a result for the development of expertise. The typical path to expertise in product development begins with an academic education and is followed by experience as a professional designer in industry. While instruction seems to be the only knowledge source on the early novice level, the importance of experience grows on higher levels

of expertise. On the highest expert level, knowledge is mainly acquired by professional experience. Creative deductive reasoning should not be considered part of the model, as it cannot be trained efficiently by an external knowledge base. Moreover, improved results are almost incapable of being measured.

Figure 2 shows the relationship between the two regarded knowledge sources and the amount of domain-specific knowledge, that increases on a general scale of expertise.

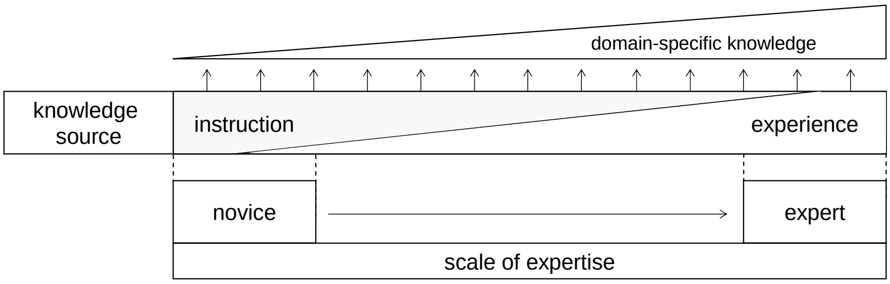

Figure 2. Knowledge sources in the context of expertise development

Within the described classification model, the expression *expertise* is used generally. As domain-specific knowlege is regarded to be essential for the development into an expert, it is defined as the base of a general scale of expertise. To reduce complexity, the amount of domain-specific knowledge shall be the scale of expertise. It is particularly important to note that both the quantity *and* quality of knowledge have to be considered. In this context, other criteria of expertise are not regarded, since the system is mainly aimed at transferring knowledge.

At the starting point of an academic education, domain-specific knowledge is solely transfered by instruction. Exercises for advanced students play an important role in gaining experience, but cannot commence until a minimum of declarative knowledge is gained. These knowledge structures are a basic requirement to improve problem-solving abilities in product development. As a result experience-based knowledge transfer starts on a higher level of expertise. It is quite obvious that experience gained in an academic environment can be compared to professional experience only to a certain degree and that real problems are usually more complex and tricky.

Even when an academic education is strongly application-oriented, the start of profession as a desinger should cause a jump in experience-based knowledge transfer. Accordingly, instruction becomes less important. It is quite evident that this event should cause considerable changes in the user's requirements. With increasing professional experience, knowledge should be represented in a more procedural structure. As mentioned above, case-based knowledge structures are mainly developed on higher levels of expertise. It can be assumed that instructions, which are transfered from academic education without any adaption, will not succeed in improving performance on higher levels of expertise. An integrated learning, teaching and application system is able to transfer knowledge, but it is limited in its ability to provide experience. Thus, users on higher levels of expertise can only be supported to a very limited degree.

Considering the three environments, potential users of an integrated support system can be classified based on a general scale of expertise as seen in Figure 3. The number of expert levels primarily corresponds to the number of different user types.

Starting at the novice level, the development of expertise covers the following levels: advanced, intermediate, experienced and expert. It is particularly important to note that knowledge does not increase continuously. As a result, the scale of expertise does not represent a contiuous spectrum, but contains different characteristic levels of knowledge. Accordingly, expertise undergoes a stepwise development up to higher levels. Restructuring processes in regard to the representation of knowledge could be responsible for this phenomenon.

The user environments described above are integrated in the classification model by introducing a learning, teaching and application context. These contexts cover a broad range from university to industry. Potential users of an integrated learning, teaching and application system are assigned to these contexts. The integration of different context spectrums seems to be essential, as user requirements depend on both the achieved level on the general scale of expertise and the specific application scenario. Application scenarios strongly influence user requirements in regard to the preparation of knowledge. For instance, users of the teaching context require product development knowledge that is adapted to a certain teaching situation, considering special didactical aspects.

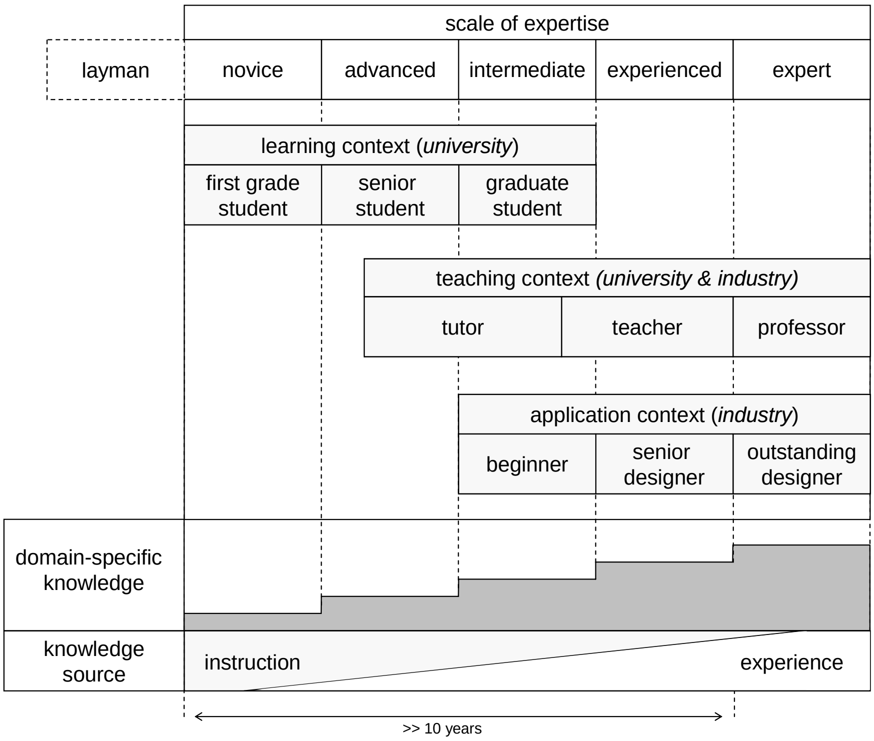

Figure 3. User classification

In principal the teaching context refers to university. Because knowledge transfer to industrial partners is regarded as an important element in the context of academic education, the teaching context has an integrating function. Therefore the teaching context also refers to the field of industry to some degree. However, learning and teaching contexts are mainly based on university and cover the whole scale of expertise. The staggered arrangement of the learning and teaching contexts results from the direction of knowledge transfer. It can be seen that users on higher expert levels (within the teaching context) transfer knowledge to lower levels (within the learning context). An overlapping of the learning and teaching contexts is caused by students teaching excercise courses. These students act as tutors within the teaching context, while they are still involved in the learning context. This example demonstrates, that a person on a certain level of epxertise can be assigned to different contexts at the same time. In general, he will have different requirements depending on the specific context.

5. Conclusion

The classification approach represents a basis for future research on user requirements. It makes it possible to classify and cluster users according to their specific level of expertise, as well as assign them to a certain application context (learning, teaching, designing context). By this means, the approach takes into account both the user's domain-specific knowledge and situational aspects. In other words, important internal as well as external criteria are considered.

The general scale of expertise used in the approach is based solely on domain-specific knowledge. As other criteria of expertise are secondary and almost incapable of being measured, knowledge seems a

solid basis for user classification. In this context, it has to be pointed out that an objective measurement of knowledge could also demand some effort.
The approach covers a broad spectrum within the academic and industrial environment, which is absolutely nessesary to appropriately classify the users of the described system. The classification reflects the entire development up to the expert level. As there are still deficits in research on knowledge structures, just some basic representation formalisms are introduced within the scale of expertise.
The classification approach not only represents a modification of existing models of expertise, but also an attempt to transfer those models into practical applications. Models that reflect the development of expertise should be particularly suitable for the regarded context, as they provide an insight to the present specific user levels. In addition, they could possibly provide information on how to reach a higher level of expertise.

6. Summary & Outlook

In this paper an approach for user classification in the context of an integrated learning, teaching and application system in product development is introduced. The classification is based on a general scale of expertise, which reflects the development from a nocive to an expert. Because the system is mainly made to support knowledge transfer in the regarded domain, the scale of expertise reflects the amount of domain-specific knowledge. In addition, different user environments (learning, teaching, application environment) are integrated. As a result a user is classified by both his level of expertise (i.e. the amount and structure of domain-specific knowledge) and the user context, which reflects his function in the process of knowledge transfer.
The approach represents a basis for the identification of user requirements within the regarded context. In the next step, different user scenarios reflecting specific situations in the process of knowledge transfer could be analysed. An integration of those scenarios should support the identification of specific user scenarios and – as a result – improve the system.

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