AN EPISTEMOLOGICAL FOUNDATION OF CONCEPTUAL MODELING[1]

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Abstract

In a business environment, making the right decisions is vital for the success of a company. Making right decisions is inevitably bound to the availability and provision of relevant information. Information systems are supposed to be able to provide this information in an efficient way. Thus, within information systems development a detailed analysis of information supply and information demands has to prevail. Based on Szyperski's information set and subset-model we will give an epistemological foundation of information modeling in general and show, why conceptual modeling in particular is capable of developing effective and efficient information systems. Furthermore, we derive conceptual modeling requirements based on our findings.

Keywords :Conceptual Modeling, Information Requirements Engineering, Language Communities

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1 INTRODUCTION

An ongoing discussion on the business value of IT (Hitt & Brynjolfsson 1996, Im & Dow & Grover 2001, Mukhopadhyay & Kekre & Kalathur 1995, Subramani & Walden 2001, Tam 1998), the role of IT in creating competitive advantage (Johnston & Vitale 1988), and the perception that IT has changed from a simple administrative support tool to the vital backbone of an organization (Henderson & Venkatraman 1999, Li & Chen 2001, Venkatraman 1994) clearly indicate that the role and impact of IT in contemporary organizations has changed significantly. In order to cope with the increased pressure on IT (Mukhopadhyay & Kekre & Kalathur 1995) as a result of these developments, the implementation of business solutions needs, more than ever to be effective, that is to meet business requirements exactly. Moreover, it needs to be increasingly efficient, requiring shorter development cycles, increased quality, and lower development costs.

From an IS perspective, a broad variety of methods, architectures, and solutions aim at supporting the information systems development process (Avison & Fitzgerald 1995, Galliers & Swan 2000, Hirschheim & Klein & Lyytinen 1995). Nevertheless, many information systems development projects fail for several reasons (Keil 1995, Standish Group International 2001). One of the reasons of the failure of IT projects is a miscommunication between business and IT personnel. Business personnel, usually, are not able to explicitly give their information requirements to IT personnel in a way that can be technically used to implement or configure a system such as a data model or a process model. IT personnel, on the other hand, usually, do not have a business background detailed enough to provide business personnel with appropriate IT solutions independently. If business requirements are badly understood by IT personnel because of an insufficiently developed language shared by IT and business, problems are unavoidable.

A shared domain knowledge between business and IT executives, positively influences the alignment of business and IT objectives and thus enhances the quality of IT solutions (Reich & Benbasat 2000). Transferable languages or a shared language to enable communication between business and IT personnel will lead to shared domain knowledge because interdisciplinary organizational members have a means to communicate. Conceptual modeling is a commonly accepted approach to overcome communication problems (Wand & Weber 2002).

To visualize and conceptualize the communication problem between business and IT, we will introduce in the next section a model that was originally developed by Szyperski (Szyperski 1980). The model identifies three communities involved in information systems development. By giving an epistemological foundation of this model in section 3, we will show in section 4 why conceptual modeling is appropriate to overcome communication problems between experts, users, and IT-personnel. Based on this, we derive requirements for conceptual modeling techniques. Finally, the findings are summarized and future prospects discussed.

2 COMMUNICATION PROBLEMS IN INFORMATION SYSTEMS DEVELOPMENT VISUALIZED BY THE SZYPERSKI-MODEL

One of the major problems in organizations is to identify and deliver relevant information to solve certain problems (Berthel 1992). Thus, Information Requirements Engineering (IRE) becomes increasingly important for organizations and thus for the development of supporting Information Systems (Ormerod & Richardson & Shepherd 1998). Accordingly, the identification and specification of information needs has been a major issue in information systems research in the last decades (Berthel 1992, Davis & Monroe 1987, Szyperski 1980). Several IRE methods and approaches (especially in the MIS domain) have been developed and evaluated (Becker, et al. 2003a, Martin 1983, Munro & Davis 1977, Sethi & Teng 1988). Some widely adopted methods are the Critical Success Factors method (Rockart 1979), document analysis, task analysis, and input output analysis (Holten

1999). Nevertheless, the problem of information requirements engineering is considered to have deficiencies in theory (Bea 1995).

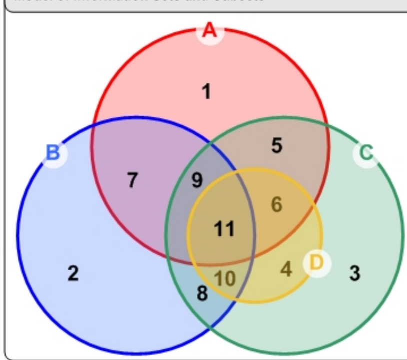
Following Szyperski (Szyperski 1980), these deficiencies arise from the complex nature of information requirements analysis (comp. Figure 1). Circle A represents the amount of information that is available in an organization. In the IS context, information is provided by ERP systems, data warehouses, or other information systems. Circle B represents the amount of information “correctly” needed to make a decision or to perform a specific task. Circle C comprises the amount of information a user considers “subjectively” to be relevant to her task or problem. Circle D contains the information the user actually is able to request in order to make a decision. This amount of information can be significantly smaller than circle C, because of the complex structure of the problem the user is confronted with and the user’s inability to express and identify her information requirements (Davis & Monroe 1987).

Usually, these circles are only partially overlapping (Berthel 1992). In the information systems development context, the following divergences can be explained as follows:

- The divergence of circles A and B denotes, that the supporting information systems provides only parts of the relevant (compare areas 7, 9, 11 in Figure 1) and additionally irrelevant information (areas 1, 5, 6). Other “correct” information is not supplied (areas 2, 8, 10). Providing only parts of relevant information and irrelevant information indicates that an information system is not fully appropriate to support the objectives correctly.
- The divergence of circles B and C can be led back to the fact, that different users have different cognitive styles and use different and sometimes inefficient strategies to make decisions (Davis & Monroe 1987, Grescher & Zahn 1992, Szyperski 1980). The “subjective” relevant information changes in time, as users learn and enlarge their knowledge. Problems of users with expressing the information requirements amplify the problem of getting the right information for individuals. Requesting irrelevant information (areas 6, 4) and being able to request only parts of relevant (areas 8, 9) and available information (area 9) will lead to a suboptimal solution of problems, too.
- The divergence of circles A and C leads to the situation that users do not accept the supporting information system, as it does not deliver the “subjectively” right information. The provision of relevant information that are subjectively irrelevant (area 7), the use of “correctly” irrelevant information (area 5), and the missing of subjectively relevant information (area 3) constitute this problem.

Thus, the set of information which is relevant, requested and deliverable contains only a small subset of relevant information (indicated by area 11 in Figure 1).

Model of Information Sets and Subsets



Main Information Sets
A: Information Supply
B: "Correct" Information Need
C: Subjective Information Need
D: Information Request

Information Subsets											
Property	1	2	3	4	5	6	7	8	9	10	11
"Correctly" Relevant		X					X	X	X	X	X
"Correctly" Irrelevant	X		X	X	X	X					
Subjectively Relevant			X	X	X	X		X	X	X	X
Subjectively Irrelevant	X	X					X				
Deliverable	X				X	X	X		X		X
Not Deliverable		X	X	X				X		X	
Requested				X		X				X	X
Not Requested	X	X	X		X		X	X	X		

Figure 1: Model of Information Sets and Subsets (Source: compare to (Szyperski 1980, column 906))

The introduced model of information sets and subsets has certain implications for information systems developments. Firstly, the starting point for information systems development must be circle B because only the information included there solves the problem properly. The information supplied by information systems (circle A) must resemble the objective information requirements (circle B) as closely as possible (convergence of circles A and B). Furthermore, the information requested by an organizational member (circle D) should largely overlap with the objective information requirements (convergence of circles D and B). Moreover, we propose to foster the understanding of complex problems (convergence of circles B and C). The overall objective, of course, must be the convergence of all four circles with circle B being the starting point.

A generally accepted way to enable communication between experts, developers, and users is conceptual modeling, as it aims to support the communication between developers and users and helps analysts to understand a domain by using a formal approach to articulate user requirements from a business perspective (Kung & Solvberg 1986, Wand & Weber 2002). We will encourage this statement in the next section via a theoretically sound foundation of our approach of applying Szyperski's model (and thus of information modeling).

3 EPISTEMOLOGICAL FOUNDATION OF INFORMATION MODELING

Every scientific model has certain epistemological implications. Some of these are inherent within the model whereas others depend on the way the model is applied in the context of a research approach. In this section, we describe five epistemological aspects that are fundamental to our research approach:

(I) Existence of a real world. The first epistemological assumption of our research approach is the existence of a real world beyond the realms of pure imagination of the subject. Thus, we presume a world that exists independently of cognition, i. e. independent of thought and speech processes. Thus, we assume the position of (ontological) realism. Hereby, we refer to ontology as the analysis or the theory of 'what is' and 'how it is' (Bunge 1977, von Foerster 1996).

(II) Subjective cognition. The second epistemological assumption is inherent to the Szyperski-Model, as circle C represents "subjectively" relevant information. The difference between an "objective or correct" information demand on the one hand and a "subjective" information demand on the other hand can be explained from a constructivist point of view. The question answered here is about the relationship of (a) cognition obtained by the subject to (b) the object of cognition. The point is whether things in the real world can at least in principle be recognized as objective. This is neglected by constructivists who assume that cognition is subjective (or "private"). The relationship of cognition and the object of cognition is thus determined clearly by the subject.

Taking into account the first epistemological assumption "existence of an objective world" and the second epistemological assumption "subjective cognition" we consider our research approach as belonging to the position of moderate constructivism (Schütte 1999) (cp. Figure 2). Due to the high level of subjectivity in the process of cognition, the process of cognition prevails as the (re)construction of reality through (predominantly linguistic) action. The quality of such a (re)construction is determined by the extent to which it can be aligned with the individual's own immediate cognition. Speech, as a central instrument of (re)construction, is, as a rule, the property of a language community.

		Epistemological position with respect to the relationship of cognition and object	
		Objective cognition is impossible.	Objective cognition is possible.
Ontological position	There is a real world	(2) Moderate constructivism	(1) Naïve realism
	There is no real world	(3) Radical constructivism	

Figure 2: Potential combinations of ontological and epistemological positions

(III) Objective or "correct" information demand is determined by a consensus of experts. According to the constructivist paradigm that no objective cognition is possible, consequently the "objective information demand" has to be put into perspective. At this juncture, we draw upon the consensus theory of truth. We understand a proposition about the "correct" or "objective" information demand as a statement which has to be proven as true or false. According to the consensus theory of truth in its rudimentary structure, truth of statements results from the consensus of everyone (Apel 1979, Baumann 2002, Habermas 1973): A statement is true if, and only if, it is acceptable for everyone. Focusing certain business problems and IS solutions suggests, that the reduction of "everyone" to a group of smaller size is permitted. In this context, the concept of the consensus theory of truth, altered to this effect, might be: A statement is true (for a group), if and only if, it is acceptable for the group. Applied to the problem of finding the "correct" or "objective" information demand, this has to be understood as: A statement about the "correctness" of information demand is true, if it is acceptable for the group of people, being experts concerning the targeted problem. This implies that truth is relative to the group of experts in which consensus was obtained about the truth or non-truth of a certain statement.

(IV) Existence of a meta-language and an object-language. To express the statements about the "correct" information demand, conceptual models are a commonly accepted approach (Wand & Weber 2002). Several modeling languages can be used, e. g. ERM or eEPC. By this means, models can be used as a formalized way of stating the experts' consensus. We assume that, firstly, within the experts' discussion a language is used which is not a formalized modeling language, but rather a natural language such as English. Secondly, we assume that conceptual models (expressed in a modeling language) are used to formalize experts' statements. Natural language (e. g., English) can be used to discuss whether the statements within a conceptual information model are "correct". Here, natural language poses as a meta-language, while the formalized modeling language (e. g., ERM) acts as an object-language. Here, we draw upon the semantic theory of truth which was coined by Tarski. This theory achieves precision of argumentation by using the instrument of modern semantics. Regarding the following remarks on the semantic theory, see (Tarski 1944, Tarski 1956, Tarski 1993) as well as (Baumann 2002, Haak 1978, Kirkham 1992, Schmitt 1995). According to the semantic theory, truth is based to a large degree on linguistics. It applies to: s, L and p:

(T) „s" is a true sentence of the object language L, if it applies: p

s: the statement of the object language, whose validity has to be proven

L: object-language, which expresses the statement, whose validity has to be proven

p: translation of the object language based statement „s" into the meta language M

M: meta-language, which contains predicates of truth regarding object-language based statements

This concept does not define the term truth. It rather expresses a condition for appropriateness, which represents the necessary requirement of a definition of the term truth (Baumann 2002). As we assumed above, truth or "correctness" of statements depends on the consensus of a group of experts. The results of such a consensus are expressed in an object-language (L). The natural language, e. g. English, contains the predicates of truth regarding the object-language based statements and poses as a meta-language (M). The differentiation between object-language and meta-language is significant. Originally, the meta-language necessarily had to be a formalized language, but attempts to enlarge this concept beyond formalized languages can be found in (Davidson 1984). With the *semantic theory of truth*, Tarski developed a concept of truth, which is always *relative* to a language (object-language). Simultaneously, the existence of a meta-language is assumed, which contains the predicates of truth about statements of the object-language. In this context, both languages ultimately emerge in language communities.

(V) Language Critique. Early research on linguistics already divided between an addressed concept and a linguistic sign. Ferdinand de Saussure conceptualized a linguistic *sign* as a union of a *concept*, or alternatively the *signified (signifié)* and a *sound image*, or alternatively the *signifier (significant)* (de

Saussure 1974, p. 66). His *Principle I* describes that the combination of concept and sound image is arbitrary (de Saussure 1974, p. 67). Later, Charles Morris defined three aspects within languages which are *syntax* as the relation of symbols to one another (Morris 1971, p. 28), semantics as the relation of symbols to concepts or objects (Morris 1971, p. 35), and pragmatics as the relation of symbols to their interpreters (Morris 1971, p. 43).

With Kamlah & Lorenzen's *Language Critique* approach, the combination of a signified and a signifier from de Saussure or semantics and syntax from Morris can be created deliberately (Kamlah & Lorenzen 1984). It becomes apparent that the consensus within a group of experts on the "correct" information demand (cp. assumption III) can only be achieved by exchanging speech artefacts. Accordingly, this requires the existence of a *language community* to guarantee the common understanding of terms to express statements (Kamlah & Lorenzen 1984). Secondly, in the context of semantic theory (cp. assumption IV) object-language as well as meta-language are ultimately the property of a *language community* as well.

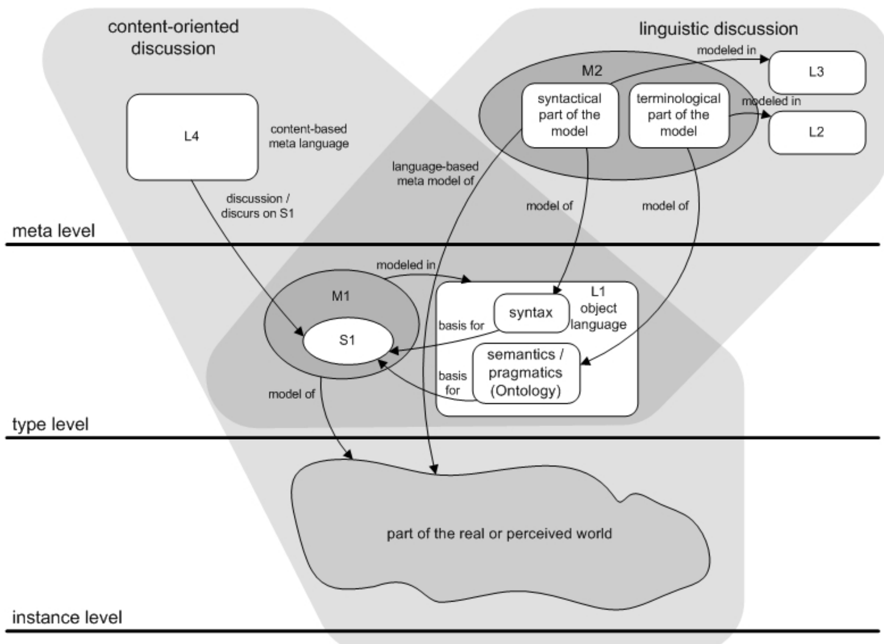


Figure 3: *Arrangement of Models, Meta Models, and Languages at Language Abstraction Levels*

The work on Language Critique, a branch of constructive philosophy (cp. assumption II) known as the "Erlangen School", of Wilhelm Kamlah & Paul Lorenzen, provides useful insights in building language communities (Kamlah & Lorenzen 1984, Lorenzen 1987). In their groundbreaking work, Kamlah & Lorenzen show that language is used to disclose the world (Kamlah & Lorenzen 1984, p. 33). By separating language and discourse in the sense of schema versus linguistic action, Kamlah & Lorenzen provide a means of separating concepts (founding a language and thus a schema) from their linguistic usage (discourse) (Kamlah & Lorenzen 1984, p. 41). As a set of concepts, language, on the one hand, is shared by a language community as common knowledge. (Kamlah & Lorenzen 1984, p. 47). The sharing and understanding of concepts by a language community is based on an agreement (Kamlah & Lorenzen 1984, p. 45). Members of the group know how to use these concepts. On the other hand, discourse means the repeatedly actualized usage of concepts in changing combination and variation. Thus, discourse is an actualized activity, whereas language comprises potential activities, defined as activity-schema (Kamlah & Lorenzen 1984, p. 45). "When we make statements about activities which are invariant with respect to accidental properties of these activities, we are talking about the activities as activity-schemata" (Kamlah & Lorenzen 1984, p. 85). The transition from an actualized activity to its schema is an abstraction. Concepts are created by an abstraction from actualized linguistic activity, and terms are syntactical representations used in a discourse (Lorenzen 1987, p. 116). This abstraction is referred to as language critical (re)construction.

In the context of information systems development, we assume that information models can be used to formalize experts' statements. Following Kamlah and Lorenzen (1984), the building of a modeling language is a process. Using the language in changing combinations and variations may lead to new language concepts, what is addressed by Kamlah & Lorenzen as language critical (re)construction. To verify the truth of a statement (consensus of experts) which is expressed through a conceptual model, the experts need to be members of a language community. Thus, they have to be capable of understanding the modeling language (object-language) and the statements that are expressed using this language. Regarding the understanding of a modeling language, language-based meta models (M2) of a certain modeling language (L1) can be used to explain modeling language elements and their relation (syntax and semantics/pragmatics). Regarding the understanding of statements, the meta language (L4), e. g. English, has to be used to discuss a statement (S1) which is expressed via a conceptual model (M1), using L1 (cp. Figure 3).

4 PROVIDING INFORMATION MODELS AND RESULTING CONCEPTUAL MODELING REQUIREMENTS

The discussion so far motivated information models expressing expert's solutions to business problems as the starting point for information systems development. In the same instance, these information models must serve as a basis for individuals who are non-experts within the problem domain to create an understanding of the different facets of the business problem. The discussions on the Szyperski-Model also motivated that information models representing expert's knowledge need to be provided to business users (circle C) and IT-developers (circle A) as non-experts. The set of information models provided by experts can be (compare Figure 4):

1. transformed into languages which can be understood by the targeted users (these users are organizational members who act as participants in internal business process or IT-developers which act as providers for information systems),
2. maintained reducing the complexity of the models (this allows for adequately providing organizational members and IT-developers with that part of the model which exactly represents the information they need to perform their tasks), or
3. maintained keeping their original complexity.

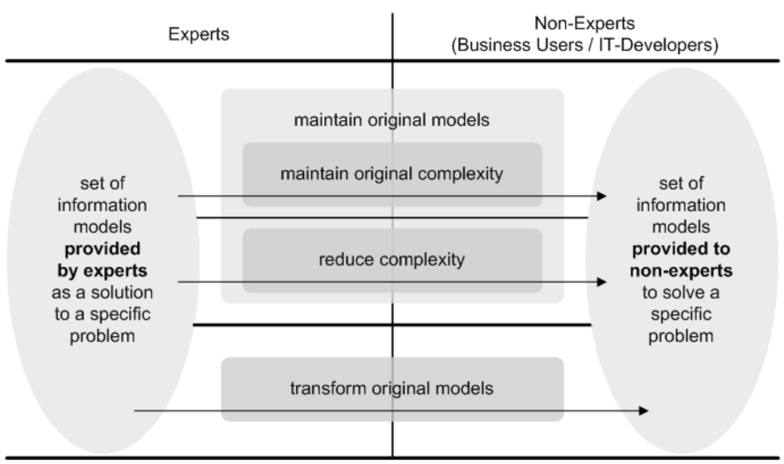


Figure 4: Information Model Provision to Business and IT-Users

With respect to the discussion of section 3, all three possibilities have certain implications:

1. For each language community within an organization the relevant set of information models needs to be transformed. In order to perform these transformations, there needs to be at least one individual who is member of both language communities, the experts' language community and the respective language community of the organizational members. This individual must either perform the transformation manually or specify rules by which a transformation can be achieved automatically. Considering the number of different roles and natural languages especially within large organizations, there maybe numerous language communities which may make language transformation inefficient or even ineffective. Furthermore, language transformation can only work if the target language in which the set of information models needs to be provided features at least the same expressive power as the source language. Otherwise some language constructs cannot be translated, which is a so-called grammatical construct deficit of the target language. In this case, an ontological construct of the source language does not map to any ontological construct of the targeted language (Ashenhurst 1996, Wand & Weber 1993, Wimmer & Wimmer 1992). Finally, the translation of a source language into various other languages leads to the use of multiple modeling languages. Two criteria need to be achieved for the effectively using multiple languages: firstly, to avoid conflicting domain representations, minimum ontological overlap (MOO) of the different languages have to be targeted (Wand & Weber 2002). Secondly, to enable complete domain representations, maximum ontological coverage (MOC) over all languages has to be achieved (Wand & Weber 2002). Thus, a careful selection of the target languages is essential (Wand & Weber 2002).
2. The complexity of the original set of information models must be as high as to represent all aspects that the entire set of targeted users requires for solving the initial business problem. Since the information models provided to users are original models of reduced complexity the languages in which original and target models are modeled share the same expressive power. The intended users of the models must be at least a member of a part of the language community of the experts in that they need a shared understanding of the symbols collaboratively used. The experts providing the information models solving the underlying business problem cannot only be experts of the business domain, but must also be experts within each of the target facet involved in solving the business problem. One remaining problem can be the acceptance of the original model. Since all problem solving competences shift to the expert group, the targeted users of the model are reduced to basic implementers. If they had more power in the past, they might resist the application of these models. A similar behavior within information systems adaptation has been observed by Markus (Markus 1983). Also in information systems development user participation and management support (both of which are model users) have been identified to contribute to systems success (Wixom & Watson 2001). Furthermore, it is unlikely that a single modeling language is able to express all phenomena as efficient as using different modeling languages with different scopes. Additionally, even if a single modeling language is capable of modeling a domain completely, the demands placed on different language users may be too high (Wand & Weber 2002).
3. Since the original models stay unchanged, experts and targeted model users necessarily constitute a language community regarding the used model language. The models used in this approach must abstract from certain aspects such as technical or organizational details. The experts providing information models as a solution to a business problem can abstract from such details and focus on the problem itself. The set on information models provided by experts constitutes a framework in which the targeted users must make extensions (e.g. constructing a physical from a logical data schema). Also, the set of experts is different in this case because they do not need to be able to solve the problem from all perspectives. In turn, the users of the models need to have problem solving capabilities because the experts' models leave certain aspects open.

The first way of providing information models to intended users is to our thinking not feasible, because too many transformations need to be performed. Especially if there are languages involved which follow completely different paradigms or if they differ highly in their expressive power, language transformation may furthermore be impossible.

The second way of providing information models to users implies the use of modeling languages with certain qualities. Firstly, they must be able to describe a solution to a business problem from an expert's perspective. Secondly, they must be able to provide models for problem solving from a user's perspective. Especially for complex problems in large organizations, a major disadvantage of this way of providing information models can be seen in the complexity of the source models. If each facet of the targeted users' requirements needs to be modeled by the expert group, information modeling can quickly become an overwhelming project. Additionally, the expert group must be differently organized as the experts do not only need to solve the problem from a business perspective but also from various other perspectives such as an IS perspective. A theoretical framework to perform such complexity reducing model configurations regarding multiple perspectives is configurable reference modeling (Becker, et al. 2002, Becker, et al. 2001, Becker, et al. 2003b). In this approach, the authors also address the problem of complexity.

Finally, the third way of providing information models, as the second way, implies the use of modeling languages which meet the requirements of both experts and non-experts. Whereas the complexity of the original set of information models in the second approach especially in large organizations is extremely high, the complexity of the original set of information models in the third approach is limited. Thus, the targeted users have to make extensions to the original set of information models, regarding the scope of requirements they have to focus on and they are experts in. Conceptual modeling techniques meet the requirements for this way of providing information models to intended users (Wand & Weber 2002). Conceptual modeling has recently gained increased attention. Contributions reach from evaluating conceptual models (Shanks & Tansley & Weber 2003) and conceptual modeling techniques (Gemino & Wand 2003) over discussions on necessary aspects within conceptual modeling (Bodart, et al. 2001) to general calls for conceptual modeling including possible research areas and problems (Wand & Weber 2002, Weber 2003).

The implications of using conceptual modeling for communicating information models from experts to users have been described above. Advantages as reduced modeling complexity for the expert's group, easy to understand models, or the inclusion of users in problem solving naturally come at cost. Conceptual modeling may pose additional efforts to the problem-solving individuals, the information models are provided to. Depending on an individual, a representation of a business problem can be more or less appropriate and influences her problem-solving capabilities (Newell & Simon 1972). However, due to the potential problems of both the first approach and the second approach to provide information models containing a solution to a business problem from an expert's perspective to intended users, we argue that conceptual modeling fits best to close the communication gap between experts and non-experts.

In order for experts to model the solution to a business problem on a conceptual level in a way that the outcome can be used by non-expert organizational members to solve the business problem, the used conceptual modeling technique must have certain features which can be derived directly from the explanations given so far:

1. The used conceptual modeling technique must abstract from technical or organizational details.
2. Since each addressed user must become part of the conceptual modeling language's language community, it must be easy to learn.
3. The used conceptual modeling technique must be formal enough to avoid misinterpretations when targeted users apply conceptual models created with this technique.
4. The used conceptual modeling technique's language constructs need to be defined ontologically sound in order to ensure the quality of the technique and allow for the technique's validation.
5. Ideally, there exist transformation mechanisms which allow for using conceptual models further consistently (e. g., deriving logical data schemas from conceptual models). At least the construction of such transformation mechanisms must be theoretically possible.

This cannot be seen as an exhaustive list of requirements but we argue that a conceptual modeling approach with these features will be able to communicate experts' problem solutions to users.

5 SUMMARY AND OUTLOOK

By introducing the Szyperski-model we visualized three language communities participated in information systems development, experts, developers, and users. We identified something initially described as objective information requirements as ideally being the starting point for information systems development. This concept has, based on our epistemological foundation, later been conceptualized as a consensus of experts. We introduced three ways of communicating this expert consensus to the targeted users within information systems development. We explained why we think that an untouched provision of these models to the targeted users is the most suitable way of providing the expert consensus. We also explained why conceptual modeling techniques meet the requirements of providing a consensus of experts to users and derived requirements for conceptual modeling techniques.

Our further research aims at delivering empirical evidence for the statements made in this paper. This includes on the one hand a comparison of the three ways of communicating experts' models. On the other hand we will work on delivering evidence that conceptual modeling is able to express solutions to business problems to several user groups in a comprehensive manner. Within this context, we will furthermore conduct case studies which will give useful insight in the applicability of the two competing approaches (maintaining complexity vs. reducing complexity). Additionally, we will continue analyzing the epistemological dimensions of the Szyperski-model and conceptual modelling in general.

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