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Evaluation of Conceptual Modeling Languages: An Epistemological Discussion

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ABSTRACT

The Information Systems (IS) discipline is coined by a multiplicity of available conceptual modeling approaches. Thus, evaluation techniques have been developed in order to assess the appropriateness of a conceptual model in a given context. Up to now, however, both modeling and evaluation approaches lack a thorough epistemological foundation and discussion, leading to problems regarding the applicability of a certain modeling language in a given context on the one hand, and regarding the feasibility of certain evaluation approaches towards certain modeling questions on the other hand. We address the question of epistemology in evaluation research and therein argue that there is an immanent need for publishing epistemological underpinnings of evaluation approaches in order to assess their applicability in given modeling contexts. We present a basic discussion framework that allows for the analysis of epistemological implications of available evaluation approaches for conceptual modeling languages.

Keywords (Required)

Science philosophy, epistemology, development methods, conceptual modeling, research evaluation

INTRODUCTION

The importance of appropriate information provision for successful businesses is widely recognized, cf. e.g. (Mukhopadhyay et al., 1995; Porter, 2001). IS implementation is usually preceded by their development through design methodologies which utilize so-called information systems models to specify the IS on an abstract, conceptual level. In this context, conceptual models that rely upon conceptual modeling languages have been successfully employed throughout IS theory and practice. This has led, however, to the proliferation of an enormous amount of available modeling approaches. This "flooding" of the discipline with a multiplicity of conceptual modeling approaches consequently leads to an immanent need for comparing and evaluating existing modeling methods in order to determine which conceptual modeling language is most appropriate for a given modeling task (Floyd, 1986; Siau et al., 1998). While evaluation approaches for conceptual modeling languages exist by now (e.g. (Frank, 1998; Wand et al., 1989)), the question remains, which of these evaluation approaches is most suitable for finding an appropriate answer in a given modeling situation. Thus, *our research objective* is to develop an approach for comparing different evaluation approaches for conceptual modeling languages in order to explicate their applicability and appropriateness for different modeling questions.

Approaching this research objective from a theoretical perspective motivates the idea of transferring insights gained from philosophy, esp. the branch of epistemology, towards the problem domain, i.e. conceptual modeling and model evaluation.

While there is plenty academic discussion on epistemological foundations of the IS discipline, cf. e.g. (Hirschheim et al., 1995), and of conceptual modeling (Frank, 1999; Niehaves et al., 2004b), the field of evaluative research still lacks a thorough epistemological discussion. Addressing this issue the *aim of our paper* is to answer the question as to what consequences certain epistemological viewpoints reveal to the evaluation of IS research artifacts, specifically conceptual models. In order to find an answer to this question we develop a basic discussion framework for analyzing epistemological underpinnings of model evaluation approaches and to evaluate their implications towards the perception and understanding of models.

The remainder of this paper is structured as follows: The next section presents an academic discussion of terms and concepts central to this research, i.e. epistemology, conceptual modeling, and model evaluation research. Section 3 presents our discussion framework for analyzing epistemological foundations of evaluation approaches. The feasibility of the framework

is demonstrated by applying it (briefly) to a commonly known evaluation approach for conceptual modeling languages, the Bunge-Wand-Weber approach. Section 4 closes this paper by presenting conclusions and future topics of research.

BACKGROUND AND RELATED WORK

Epistemology in IS Research

The Information Systems (IS) discipline is relatively new. It evolved at the intersection of historically well-established research fields such as Management Science, Technology Science, Social Science etc. Moreover, researchers studying in the IS area are originally coming from disparate research disciplines, bringing with them not only a range of methods and methodologies but also a diversity of underlying philosophical assumptions towards research, and – going deeper – understanding and cognition of reality, language, and truth. However, as we understand our discipline as concerned with "the effective design, delivery, use and impact of information technology in organizations and society" (Avison et al., 1995), p. xi, we feel that it is – opposed to some of its so-called "foundational research disciplines" – quite uniquely placed at the interface of technology and organization, i.e. it addresses the interaction in human-machine systems: "research in the information systems field examines more than just the technological system, or just the social system, or even the two side by side; in addition, it investigates the phenomena that emerges when the two interact." (Lee, 2001), p. iii.

This tapestry of diversity in IS research leads to an urge for publishing underlying philosophical assumptions of research work so that fellow researchers and other readers fully comprehend the research approach and the perspective taken by the researcher (Ribbert et al., 2004). Furthermore, an evaluative criticism of research work is not possible without understanding the perception of science underlying the research to be evaluated.

While it is not the purpose of this research to fully investigate all parts of philosophy, it is nevertheless essential to delineate specific philosophical terms of interest: epistemology (in a broader sense) refers to the branch of philosophy that addresses knowledge, its nature and sources, and particularly the acquisition of knowledge (Hirschheim, 1985). To be more concise, epistemology denotes the study of "(a) the defining features, (b) the substantive condition of sources, and (c) the limits of knowledge and justification" (Moser, 1999), p. 273.

Out of different central questions that reveal pertinence with respect to epistemology in IS research – see e.g. the framework developed by NIEHAVES (Niehaves et al., 2004b), two main aspects are selected that form the "Weltanschauung" (world view, (Inwood, 1995)) on which evaluative research is here discussed. Specifically, we identify two epistemological assumptions, and two contrary positions within these, that form different paradigms towards IS research (for a more thorough discussion of different IS research paradigms based on multiple philosophical criteria refer to (Niehaves et al., 2004a).

Epistemological assumptions that reveal significance to this research context include the aspects of epistemology that deal with the object of cognition (ontological aspect) and with the relationship between cognition and the object of cognition (epistemological aspect in a narrower sense).

The ontological aspect refers to the question whether the object of cognition exists beyond subjective imagination and perception (Bunge, 1977). Ergo, a researcher has to position himself in terms of the assumption "existence of an objective reality". For simplicity reasons, we only differentiate two contrary positions:

- (ontological) realism: There is an objective reality existent independently from subjective cognition, i.e., independent from thought and speech.
- (ontological) idealism: There is no objective reality existent, it is dependant on subjective perception, cognition, and language.

The epistemological aspect refers to the question whether an objective recognition of things is possible beyond subjective perception. Again, for simplicity reasons, we differentiate two basic positions:

- (epistemological) realism: Objective cognition of an independent reality is possible for cognitive subjects.
- (epistemological) constructivism: Perception of a reality is always subjective ("private"), thus dependant on the cognitive subject.

Considering these epistemological and ontological positions, we can identify and differentiate the two most dominant research paradigms in the IS discipline (Chen et al., 2004):

- In terms of *positivism*, the world is objectively and in principle real and can objectively be perceived without subjective biases (Weber, 2004).

- In terms of *interpretivism*, the world is objectively real; nevertheless, the cognition process is subject dependant. Reality perception is thus susceptible to a (predominantly linguistic) (re-) construction of the cognition of reality (Weber, 2004).

Conceptual Models in IS Development

Over the last decades, conceptual models have been employed to facilitate, systemize, and aid the process of information system engineering. Conceptual models describe object systems (e.g. an information system) of some domain in semantic terms, using an abstract, yet formalized language (Khatri et al., 2004; Wand et al., 2002). Purposes served by conceptual models in the context of IS development include communicating between developers and users, thereby bridging the misunderstanding gap between requirements analysis and system implementation specification (Ambrosio et al., 1997). Further purposes of conceptual models include: helping analysts to understand a domain, providing input to the design process, and documenting the requirements for future reference (Wand et al., 2002). The popularity of conceptual models in the IS discipline has also been expressed by proposing them as the core of the IS discipline (Frank, 1999; Weber, 2003).

The quality of conceptual models is believed to have an enormous impact on the development and utilization of IT and IS artifacts, as conceptual models used in the requirements specification phase of a system development process determine the acceptability and usability of the product to be built (Lauesen et al., 2001). As the cost of fixing errors grows exponentially as an elapsed time to discovery (Moody, 1998), the importance of an adequate problem and domain representation through conceptual models is widely recognized. Conceptual models may reveal errors such as faulty requirements specification in an early stage of system development.

As the applicability, feasibility and – more generally spoken – the usefulness and quality of conceptual models is determined and restrained by the underlying conceptual modeling language, evaluation of conceptual models must primarily be concerned with the assessment of the languages. Consider e.g. an object-oriented modeling language that doesn't include the concept of generalization. Models based on this language consequently cannot allow for the concept of generalization. Likewise, models that rely on a modeling language whose semantics are not unambiguously defined will also lack an unambiguous understanding. Concluding, the underlying conceptual modeling language determines the quality of conceptual models (Frank, 1998).

IS Model Evaluation Research

Scientific research is based upon the idea of progress; hence it must comprise approaches for differentiating between competing alternatives. Thus, evaluation must be seen as a core substantive element of IS research. The importance of rigorous evaluative research can be stated as follows: "No problem-solving process can be considered complete until evaluation has been carried out. It is the evaluation which helps us to measure the effectiveness of the problem-solving process and the problem solver in the 'problem situation' – unless this element is considered there is no way of establishing that the 'problems' have been successfully resolved" (Jayaratna, 1994), p. 108.

The development of evaluation theory and practice is at the core of multiple disciplines, as is the discipline of Information Systems in general. For instance, STUFFLEBEAM (Stufflebeam, 2001) identified and evaluated twenty-two generic program evaluation approaches. In the IS field, evaluation is recognized as a constituent part of IS research (Bjørn-Anderson et al., 1988; Hevner et al., 2004). The aim of IS evaluation research is to produce appropriate answers to the questions of usefulness, effect, and impact of an IS artifact through the application of systematic studies (Wynekoop et al., 1997).

While there are several attempts to comparing modeling methods, for an overview refer to (Siau et al., 1998), there are only a few attempts that satisfactorily focus on modeling languages. Although some of the method evaluation techniques include the evaluation of language aspects they usually do not distinctively separate the evaluation of modeling languages from other parts of the method, cf. e.g. (Strahringer, 1996). Most of the publications explicitly evaluating modeling languages propose reference frameworks for evaluation comprising requirements for models, and discuss the extent to which languages fulfill these requirements. For instance, MOODY and SHANKS evaluate the ERM notation with respect to the criteria simplicity, understandability, flexibility, completeness, integration, implementability (Moody et al., 1994). Similarly, KROGSTIE *et al.* assess models based on different perspectives, distinguishing criteria like social, syntactic, semantic, and pragmatic quality (Krogstie et al., 1995). KUNG proposes the features of understandability, expressiveness, processing independence, checkability, and changeability that should be fulfilled by conceptual data models (Kung, 1983). BECKER *et al.* assess the quality of models based on specific design recommendations for enhancing the model quality beyond the fulfillment of syntactic rules (Becker et al., 1995). KESH proposes a framework for evaluation consisting of the dimensions behavior and ontology, and with each of these dimensions comprising multiple facets, such as appropriateness, adequacy and reliability in terms of behavior, and structure and content in terms of ontology (Kesh, 1995). He determines the quality by calculating metric scores for attributes that are related to the criteria mentioned above.

Summarizing, most of the approaches presented above, although not explicitly restricting it, focus on evaluating data models like the ERM notation. All of them can be characterized as either metrics or feature comparison approaches. Not to underestimate the criteria they propose but they clearly do not suffice to comprise all facets of a comprehensive investigation of modeling languages. As they don't, the need for explicating their paradigmatic suitability and feasibility for certain modeling questions becomes visible.

AN EPISTEMOLOGICAL DISCUSSION OF MODEL EVALUATION

Like any other research, evaluation research is determined and underpinned through certain philosophical research paradigms. As the IS discipline is believed to reside in a state of paradigmatic diversity, i.e. several philosophical viewpoints determining certain research actions co-exist in the field, one has to pay special attention to the implications and inter-relationships of philosophical viewpoints upon science and research and, concordantly, to the evaluation of such research process and progress. Different world views of researchers designing evaluation approaches serve the basis for evaluation, e.g. by coining the understanding of model purpose and model quality. These philosophical understandings are not subject to evaluation themselves due to the paradigmatic incommensurability problem connected (Schütte, 1999). However, a discussion of these assumptions aids explicating the approach and thus increasing the understanding for what kind of evaluative statements can be derived by applying a certain evaluation approach in a given context.

Here, a framework is presented to aid the discussion of evaluation approaches for conceptual models. As discussed above, epistemological positions have a significant impact not only on the development and embodiment of modeling methods but furthermore on the perception of models, on the question how truth (in the form of models) can be obtained, and on the results generally achievable through evaluation. In order to guide the process of explicating hiding underpinnings presuppositions and epistemological implications and consequences on certain evaluation approaches, we construct a two-dimensional discussion framework.

Its first dimension consists of the two epistemological paradigms introduced above, namely interpretivism and positivism. Note here that, obviously, the framework is extensible towards other paradigms, consider e.g. post-approaches such as radical constructivism, critical realism, or post-modernism approaches to IS research. The second dimension of the framework embraces the following discussion aspects that denote features of relevance in an evaluative context. Note here that the aspects of the second dimension are dependent on the first dimension:

- model perception: This point refers to epistemological consequences on the perception of the terms "model" and "modeling". For instance, interpretivists may favor a construction-oriented model perception that incorporates modeling subject and modeling purpose as important term defining factors, cf. e.g. (Davies et al., 2002), while positivists may argue for a pure representation-oriented model perception.
- evaluation perception: This point refers to epistemological consequences on the perception as to how evaluation can be conducted. E.g., positivists may judge modeling language sufficiency by comparing it against a taxonomy of reality constructs in an ontology while interpretivists may argue for consensus-oriented approaches towards model evaluation (Frank, 1998), i.e. investigating a model's quality in a discursive evaluation among a group of experts.
- quality perception: This point refers to epistemological consequences on the perception of quality. E. g., for positivists, the quality of a model is determined through its representation compliance to reality, whereas for interpretivists, the perception of quality is subject- and purpose-oriented and has thus to be judged within the modeling context it was designed for.

Figure 1 shows the epistemological discussion framework as proposed here. It has to be noted that this framework is considered extensible towards other paradigms and further discussion aspects.

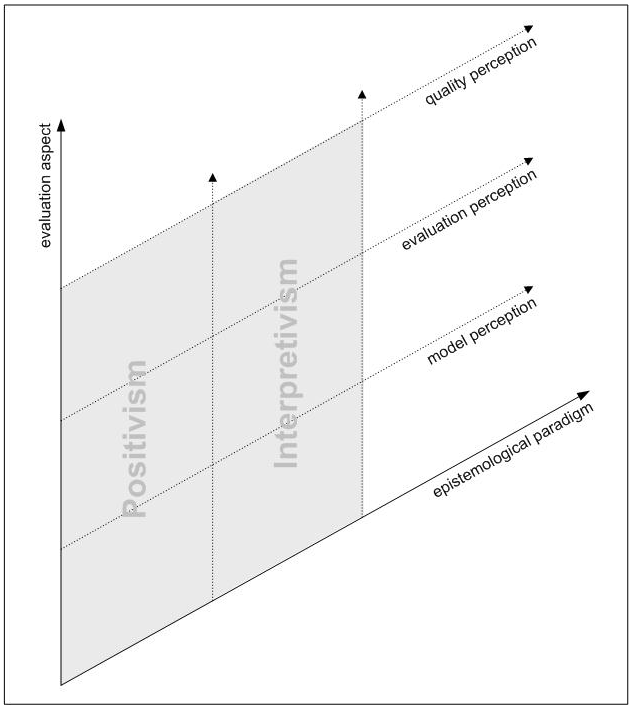

Figure 1. Epistemological Discussion Framework

In order to demonstrate the feasibility of the discussion framework, we applied it to a commonly known evaluation approach, namely the evaluation of modeling language through the BWW ontology (Wand et al., 1989).

In short, WAND and WEBER applied an ontology (a set of constructs and terms sufficient for describing reality) developed by Bunge (Bunge, 1977) to the field of conceptual modeling. The BWW ontology serves as a reference point in evaluation, specifying reality constructs that a conceptual modeling language should be able to depict. The evaluation is conducted by mapping language constructs against ontology constructs and thereby assessing ontological completeness and ontological deficiency within the modeling language (Wand et al., 1993).

Applying the discussion framework to the BWW approach, the following results have been obtained (cf. Table 1).

Analysis criterion	Criterion value
Model perception	Being followers of a positivist research approach, Wand and Weber take a both ontological and epistemological realistic position, believing that the world is made up of things that "really exist in the world." (Weber, 1997), p. 34. Therefore, the universe of discourse (UoD) comprises immutable objects and object structures that exist as empirical entities. Consequently, models of the UoD exist independently from any observer's perception. Therefore, a conceptual model is a descriptive representation of the UoD. The model perception is more that of a reproduction or representation than that of a (re-) construction. A conceptual model is, in this perception, regarded to as an objective perspective upon reality through which observers can perceive reality (unbiased).
Evaluation perception	Following a positivist research approach, the evaluation of models and conceptual modeling languages refers to an investigation of how well a model represents reality. The ontology, as a taxonomy of concepts and their

	relationships being able to depict reality sufficiently, hereby serves as a reference point for evaluation. Evaluation in the BWW approach following this perception refers to a structural analysis of analogies and dissimilarities between conceptual modeling language constructs and ontology constructs.
Quality perception	For positivists, the quality of a model is determined through its compliance to reality. In this case, the quality of a model is expressed through the degree of ontological completeness and ontological clarity of a conceptual modeling language. The quality perception does not include any reference to purpose, developer, or addressee of the artifact and it is thus solely based on semantics and syntax, leaving out domain-specific or pragmatic quality aspects. Quality of a model is in this belief expressible through the number of 1:1 mapping relationships of language constructs to ontology constructs.

Table 1. Epistemological discussion of the BWW evaluation approach

Following these elaborations, it is clear that ontological evaluation through the BWW models is restricted to model contexts adhering to the same paradigm. From an interpretivist viewpoint, the approach is insufficient. This can be explained through the fact that in interpretive research, any perception of some kind of reality is always "private", i.e. subjective. As the BWW model does not include subjective aspects into their evaluation approach, consider e.g. modeling purpose, modeler's view, model addressees etc., it cannot be claimed useful for such modeling contexts. Accordingly, models developed or utilized in research contexts that favor for different research values and norms cannot rely on the evaluation results obtained through the BWW approach. Or, in other words, the BWW approach only reveals relevance in terms of evaluation when considered in research contexts that adhere to a positivist view of research and in which the artifact under consideration, i.e. the model, is perceived from a positivist viewpoint.

These findings go alongside with the paradigm incommensurability thesis stating that a) researchers must adhere to a single philosophical paradigm throughout all stages of research and b) multi-paradigm research approaches are proscribed (Mingers, 2001). With regard to evaluation research, we believe that the paradigm incommensurability problem must be of even more concern; as certain dichotomies exist between epistemological positions that result in strictly opposing viewpoints towards research, e.g. alternative competing truth perceptions, cf. e.g. the rather positivist correspondence theory of truth (Kirkham, 1992), which denotes the essence of the BWW approach (Wyssusek, 2004), versus the rather interpretive consensus theory of truth (Habermas, 1973), which e.g. is followed in a consensus-oriented discursive evaluation approach (Frank, 1998). Thus, we argue that researches have to commit themselves to a single paradigm not only during the development of artifacts but also during the evaluation of these.

CONCLUSIONS AND OUTLOOK

This work demonstrated that evaluation is markedly problematic due to the complex nature of both evaluation itself and the object of investigation as such. As both aspects, evaluation and evaluation object, are subject to individual epistemological viewpoints, these assumptions need to be thoroughly explicated in order to fully comprehend the research context. This paper presented a basic discussion framework that can be used to provide more epistemological rigor in evaluation research by explicating philosophical presuppositions that underpin evaluation approaches. Exemplarily, the application of the framework to the BWW approach revealed that the positivist paradigm underlying the BWW approach restricts its applicability to research artifacts that comply with this paradigm.

Resulting from this research, we want to raise awareness for epistemological rigor in IS research. As has been said, epistemological assumptions not only determine artifact creation but also artifact evaluation. We conclude mainly two facts from our research:

1. Researchers need to explicate their philosophical stance clearly during all research process and progress, not only during the creation of research artifacts but also during the evaluation of these. This results from the fact that development and evaluation depict two sides of the same coin, i.e. rigorous research.

2. We proscribe multi-paradigmatic research approaches within or in between these two phases of research, development and evaluation. We argue that the evaluation of artifacts must be conducted in compliance to epistemological presuppositions that determined the artifact creation process in the first place because otherwise different perceptions of the artifact, of its purpose and quality may be applied to the research context resulting in findings that cannot comply with the research objective, context, and purpose.

Thus, researchers have to maneuver carefully through existent methods both for artifact development and validation to select appropriate, i.e. epistemologically compliant approaches within their research context. The discussion framework presented in this paper can be used as a guideline towards answering this question.

Our future research work includes refinement and extension of the discussion framework to incorporate more discussion aspects on the one hand and further paradigms based on certain epistemological positions, specifically more of the so-called post-approaches. Also, we will validate the feasibility of our discussion framework by applying to several, epistemologically different evaluation approaches for conceptual modeling languages.

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