Jabbari Sabegh, Mohammad Ali, Lukyanenko, Roman, Recker, Jan C., Samuel, Binny, & Castellanos, Arturo
(2017)
Conceptual modeling research in information systems: What we now know and what we still do not know. In
16th AIS SIGSAND Symposium, 19-20 May 2017, Cincinnati, OH.

Conceptual Modeling Research in Information Systems: What we now know and what we still do not know

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ABSTRACT

Much of conceptual modeling research over recent times has been guided by a seminal research agenda developed by Wand and Weber (2002), which identified twenty-two research opportunities. In this paper, we explore whether existing research has provided sufficient answers to these questions. Our findings from a review of the literature show a dialectic: several of the opportunities noted in 2002 have been addressed substantially while others have been entirely neglected. We also found several path breaking studies that addressed problems not spotted by the initial framework. To stimulate a forward-looking wave of conceptual modeling research, we provide a new framework that draws the attention of conceptual modeling research to the interplay between digital representations and outcomes.

Keywords

Conceptual modeling, research opportunities, literature review, research agenda

INTRODUCTION

Conceptual modeling has long been regarded a niche topic of interest to the community of scholars interested in systems analysis and design. A seminal event in the history of conceptual modeling research that brought the topic to the mainstream area of information systems (IS) research was the publication of a research framework and agenda by Wand and Weber (2002). This publication stimulated studies that answer questions regarding how to create high-quality conceptual models to better facilitate developing, implementing, using, and maintaining more valuable IS.

Wand and Weber (2002) proposed several research opportunities based on four main concepts of conceptual modeling research: conceptual modeling grammar, method, script and context. Fifteen years after its publication, we evaluate whether the original research questions by Wand and Weber (2002), or the answers provided to them, have been sufficient.

In this paper, therefore, we pursue a two-fold objective. First, we examine the published research on conceptual modeling since the publication of the Wand and Weber (2002) paper. We synthesize relevant studies on conceptual modeling that in our view contribute to and shape our understanding of the conceptual modeling discipline, and then identify the remaining gaps in the field that need further investigation. Second, we also ask whether the framework by Wand and Weber (2002) remains ideal to this day or whether a new agenda should be set. In addressing both objectives, our paper provides a comprehensive retrospective perspective on conceptual modeling research, as well as substantive generative directions for future research. In this abbreviated paper, we highlight *some* aspects of both perspectives.

REVIEW PROCEDURES

Our literature review method involved four steps (Webster and Watson 2002; Paré, Trudel, Jaana and Kitsiou 2015).

1. We selected our sample: we considered studies published in the *AIS basket of eight journals* (Liu and Myers 2011), as the representative for mainstream high-quality research in IS, and the *Journal of Database Management* because this journal has traditionally been one of the leading substantive journals publishing studies on conceptual modeling.
2. We performed a full-text search in all papers in the selected journals using relevant keywords since 2002. We retrieved 3,546 papers by October 2016. We then excluded all papers that used the term conceptual model to refer to a theory or research framework, in which we reduced the total to 105 relevant papers. The summary of the keywords, search results and

distribution of the papers are omitted from this paper to conserve space.

3. We developed and applied a coding scheme (available from the authors) to categorize each paper alongside multiple broad dimensions of *focus* and *goal*, prominent conceptual modeling *element* addressed (building on the classifications used in Wand and Weber 2002), research *method* used, and *evidence* obtained if any.
4. To ensure a reliable application of the coding scheme, one of us coded all 105 papers whilst a second author independently coded a random subset of 30 papers. Their inter-coder agreement was 62%. The two authors then discussed disagreements, updated coding criteria and instructions, and then independently revised the coding over two more rounds until 100% agreement was reached. The first author then revised the coding of the remaining 75 articles.

ANALYSIS OF THE LITERATURE

In this section, we present a brief overview of the findings from our analysis with respect to the four main conceptual modeling categories. First we offer three general observations: (a) 46% of reviewed studies were published in the *Journal of Database Management*; *(b)* more than 37% of the published studied concentrated on more than one element of conceptual modeling (e.g. grammar and script) together; and (c) UML and ERD were the most popular grammars investigated in the literature. Table 1 summarizes papers on the research opportunities proposed by Wand and Weber (2002), aggregated by focus and differentiated by type of contribution.

Element	Focus	#	#	Contribution
Conceptual Modeling Grammar	Evaluating ontologies based on empirical testing of their predictions	0		
	Evaluating grammars for ontological expressiveness	6	1	Empirical
			5	Non-Empirical
	Assigning ontological meaning to constructs of design grammars and generating ontologically motivated modeling rules	8	5	Empirical
			3	Non-Empirical
	Resolving outstanding ontological problems that impact conceptual modeling-e.g., nature of the part-of relationship	2	1	Empirical
			1	Non-Empirical
	Empirically testing predicted strengths and weaknesses in new and existing grammars based on their ontological expressiveness	0		
	Determining which combinations of grammars best support users who undertake conceptual-modeling work	0		
	Empirically testing the predicted implications of construct deficit and overload in grammars	10	10	Empirical
	Grammar-Other	6	3	Empirical
			3	Non-Empirical
Conceptual Modeling Method	Evaluating how well different methods allow users to elicit and model critical domain knowledge	9	8	Empirical
			1	Non-Empirical
	Developing procedures to assist users of a grammar in identifying and classifying phenomena according to the grammar's constructs	19	8	Empirical
			11	Non-Empirical
	Determining the beliefs and values that underlie different methods and evaluating the consequences of these beliefs and values for practice	1	1	Empirical
	Method-Other	9	6	Empirical
			3	Non-Empirical
Conceptual Modeling Script	Evaluating competing scripts generated via the same grammar to describe some phenomenon	21	21	Empirical
	Evaluating competing scripts generated via different grammars to describe the same phenomenon	3	3	Empirical
	Evaluating different combinations of scripts to determine which combination best supports the task at hand	0		
	Developing theory to predict and understand how humans use scripts to accomplish various tasks	4	3	Empirical
			1	Non-Empirical
	Scripts-Other	9	3	Empirical
			6	Non-Empirical
Conceptual-Modeling Context, Individual Differences	Development of knowledge-based tools to support conceptual modeling	5	5	Empirical
	Predicting which cognitive and personality variables bear on a user's ability to undertake conceptual-modeling work	17	11	Empirical
			6	Non-Empirical
	Predicting and testing empirically which social skills affect the outcomes of conceptual modeling tasks	1	1	Non-Empirical

		Individual difference factor-Other	1	1	Empirical
	Task	Evaluating the strengths and weaknesses of conceptual modeling grammars, methods, and scripts in the context of different tasks	4	3	Empirical
				1	Non-Empirical
		Task factors-Other	5	3	Empirical
				2	Non-Empirical
	Social Agenda	Understanding which values and beliefs underlie conceptual-modeling work in practice	3	3	Empirical
		Determining the costs and benefits of adopting different values and beliefs when undertaking conceptual-modeling work	0		
		Articulating detailed conceptual-modeling procedures that are congruent with different beliefs and values	0		
		Understanding how existing conceptual modeling grammars and methods facilitate conceptual-modeling work under different values and beliefs	0		
		Social Agenda factors-Other	2	1	Empirical
				1	Non-Empirical
Other		Papers that did not match the research framework by Wand and Weber (2002)	21	2	Empirical
				19	Non-Empirical

Table 1. Papers on Conceptual Modeling Elements by Type of Contribution

Conceptual Modeling Grammars

The dominant findings of research on modeling grammars were that any one grammar has some level of construct deficit (Recker, Rosemann, Indulska and Green 2009; Irwin and Turk 2005), and that the diagrams created with the ontologically motivated rules lead to better domain understanding (Bera, Krasnoperova and Wand 2010). However, there were also some contrary findings about the effect of construct overload on clarity and usefulness of conceptual models (e.g., Shanks et al. (2008) vs. Bowen et al. (2009)).

6 studies did not fall in any grammar-related research opportunities. Three main themes emerged from these studies. First, researchers highlighted the importance of factors other than ontological elements (Figl, Mendling and Strembeck 2012; Clarke, Burton-Jones and Weber 2016); second, some studies examined factors affecting usage behavior of grammars (Dobing and Parsons 2008; Recker 2010), and third, research addressed the complexity of grammars and difficulties in learning how to use them (VanderMeer and Dutta 2009).

Conceptual Modeling Methods

Research on modeling methods mostly focused on developing rules and methods (Poels, Maes, Gailly and Paemeleire 2011; Poels 2011) to assist users of grammars (Parsons and Wand 2008), and reducing the variety of developed models (Hadar and Soffer 2006). The dominant idea emerging from research in this category was that cognitive principles and ontological guidelines can assist users of grammars (Bera et al., 2010).

9 studies did not fall in any method-related research opportunities. One of the arguments of this line of work was that ontological guidelines, per se, cannot sufficiently cover the problems of conceptual modeling (Clarke et al., 2016). Second, researchers suggested methods to overcome problems such as information loss (Lukyanenko, Parsons and Wiersma 2014) and to improve quality of mappings and transformations of conceptual schemas to designed platforms (An, Hu and Song 2010; Pardillo, Mazón and Trujillo 2011).

Conceptual Modeling Scripts

Four main themes emerged from studies on scripts: first, evaluations of scripts developed using the same grammar based on ontological factors. This stream of work has argued that ontological clarity improves the performance of model users (e.g., Parsons 2011; Bowen, O'Farrell and Rohde 2006). However, some studies also provided contradictory results (Bowen et al., 2009; Bera, Burton-Jones and Wand 2014). Second, evaluations of different scripts developed using different grammars (Figl et al., 2012; Khatri, Vessey, Ramesh, Clay and Park 2006). The dominant findings of this stream of research are that notational deficits that exist in some grammars increase cognitive load. The third theme was that using high-quality information in different formats improves users' performance (Burton-Jones and Meso 2008). The fourth theme was that following ontological guideline to develop models decreases both developers' and model readers' cognitive difficulties (Bera et al., 2010; Bera 2012).

9 papers did not fall in any categories on modeling scripts. Two main outcomes emerged from these studies; first, sets of quality measures that relate to modeling scripts (Siau 2004; Krogstie, Sindre and Jørgensen 2006); second, the use of different types of additional information in support of modeling scripts (Burton-Jones and Meso 2008; Gemino and Parker 2009). The most notable unanswered opportunity in this category concerns the lack of empirical investigations on the use of multiple models.

Conceptual Modeling Context

Individual Difference Factors

The main themes arising from this stream of research were, first, the importance of the use of collected and learned knowledge in conceptual modeling (Purao, Storey and Han 2003; Koschmider, Song and Reijers 2010); second, aspects of traceability of the system (Pardillo et al., 2011; Loucopoulos and Kadir 2008); third, the importance of cognitive and personality variables (Davern, Shaft and Te'eni 2012; Browne and Parsons 2012); and fourth, the relevance of support from managerial teams (Bandara, Gable and Rosemann 2005) in conceptual-modeling work.

Task Factors

The main foci were the effects of differences in task settings (Recker 2010), the purpose of conceptual modeling (Green and Rosemann 2004; Recker, Indulska, Rosemann and Green 2010), and different stakeholders involved in conceptual modeling (Green and Rosemann 2004).

Several researchers identified the availability of tools for different tasks as an important factor in conceptual modeling (Bandara et al., 2005; Recker 2012). Other important task-related factors identified were domain tangibility (Soffer and Hadar 2007), the modeling grammar choice in dependence of a task (Bandara et al., 2005), and task complexity in general (VanderMeer and Dutta 2009).

Social Agenda Factors

One of the main arguments that emerged from studies in this classification was that the definitions of success may differ by the unit of analysis (e.g., developer, project, organization) and that the relationship among these definitions is complex (Hadar and Soffer 2006; Larsen, Niederman, Limayem and Chan 2009). Another study revealed that modeling conventions play an important role in the process of conceptual modeling (Recker 2010).

Two studies examined opportunities in addition to those proposed by Wand and Weber (2002). The first emerging idea was to use knowledge from social networks in order to improve the quality of conceptual models (Koschmider et al., 2010). The second emerging idea concerned environmental considerations during conceptual modeling (Zhang, Liu and Li 2011).

Articles that did not match the research framework by Wand and Weber (2002)

21 papers did not fall in any categories of the research framework proposed by Wand and Weber (2002). We identified four additional main streams from these studies: first, multidimensional conceptual modeling (Trujillo, Luján-Mora and Song 2004; Garrigós, Pardillo, Mazón, Zubcoff, Trujillo and Romero 2012); second, quality of knowledge engineering (Chua, Storey and Chiang 2012); third, a complementary role of ontologies (Fonseca and Martin 2007), and forth, different aspects of model-driven architecture engineering, such as security features (Fernández-Medina, Trujillo and Piattini 2007; D'aubeterre, Singh and Iyer 2008) or software configuration and design patterns (Dreiling, Rosemann, Van Der Aalst, Heuser and Schulz 2006; Vergara, Linero and Moreno 2007).

GUIDING THE NEXT WAVE OF CONCEPTUAL MODELING RESEARCH: A NEW FRAMEWORK

Based on our literature review, we believe that Wand and Weber's (2002) framework was useful and necessary at its time. It organized key aspects of conceptual modeling research to progress and assisted in ascertaining conceptual modeling's place as a core research stream in IS. The volume of literature published since 2002 also suggests that the framework served its purpose of guiding the community of researchers.

However, in our own use of the framework for research and for the purpose of this literature review, we identified several reasons why we believe that a new framework may be more suitable to guide the next wave of conceptual modeling research than simply following-up on the outstanding research opportunities we identified above. Our main reasons are the following:

1. Wand and Weber's framework is **script-centric**; it places the creation of modeling scripts (via grammars, methods and in a context) at the core of modeling activity. This, for example, makes it difficult to accommodate cases where the modeling activity does not give prominence to modeling scripts.
2. The framework is focused on supporting **IS development** (via modeling). While IS development is a major part of IS, the exisiting framework prohibits consideration of the use of existing IS, interaction with the data provided through an IS (e.g., business analytics) or indeed any impacts that stem from the use of IS (i.e., outcomes).
3. The framework is coined by the tacit assumption that modeling is typically undertaken by **professional IS analysts**, knowledgeable in appropriate methods and grammars. Recently, however the proliferation of content-producing technologies that may support creation of digital representations by ordinary people (e.g., Twitter's hashtags), raises questions about modeling performed by ordinary people which may be more creative and spontaneous than the traditional process (Lukyanenko, Parsons, Wiersma, Wachinger, Huber and Meldt 2017; Chang 2010; Ramesh and Browne 1999).
4. Consistent with the decades of conceptual modeling research preceding the framework where many modeling grammars and approaches have been proposed, the framework emphasized **evaluation of**

existing grammars, potentially to the neglect of the design of entirely novel modeling artifacts or approaches. The dramatic changes to the information technology landscape, however, call for revisiting traditional design assumptions and suggests development of novel conceptual modeling methods, grammars and scripts. An already debated instance in this context is the use of conceptual modeling for agile development (Erickson, Lyytinen and Siau 2005; Lukyanenko, Parsons and Samuel 2015) to name just one example.

5. The framework is **technology-agnostic**. With a steady availability of design automation tools (Orlikowski 1993) and the increasing prevalence of technologies with inherent agency even without human interventions, the modeling of domains, existing or future, is not necessarily a function of human conceptualization or behavior alone any more. Mining techniques that construct process models from event logs automatically are a case in point (van der Aalst 2011). This calls for consideration of direct technology support, enablement or even embodiment of conceptual modeling.
6. The framework is **static** and does not explicitly consider feedback resulting from the creation and use of modeling. This makes it difficult to accommodate multi-stage study designs, such as action design research (Akhigbe and Lessard 2016; Sein, Henfridsson, Purao, Rossi and Lindgren 2011) involving modeling phenomena.

In sum, while the Wand and Weber (2002) framework remains reflective of existing practice and has been useful to the academic discourse up to this day, it under-represents the ever-widening spectrum of phenomena that can be supported by conceptual modeling. Therefore, in what follows we propose a new framework with the objective of capturing both the traditional as well as emerging opportunities.

Key to the new framework is the view that a *digital representation of reality* - which lies at the core of conceptual modeling research - is becoming a major societal force as information technology increasingly entwines with all human activities (Leonardi 2011). Representations can be either formal or informal conceptualizations of user views and information requirements, structure and behavior of information systems, personal, social and business processes and existing information records. Representations can take forms of diagrams (e.g., such as ER diagram), but can also include narratives, images, and other multimedia forms. From a cognitive perspective, the representations we refer to are considered external representations (Zhang 1997); artifacts that exist outside of any one individual's mind and contain knowledge and structure about a domain.

As human reliance on IS for daily functions grows, people routinely reason and act based on their perceptions of representations of reality stored in digital systems and increasingly shun direct and traditional interactions. Floridi (2012) coins this on-going process the "enveloping" of society by an ever-increasing digital layer. We believe conceptual modeling research brings an important array of theories, tools, methods and objects of research to develop, support and interpret modern digital representations. While representations are a research object for many scientific disciplines (Hoyningen-Huene 2013), the IS conceptual modeling community has unique expertise investigating representations in the context of information technology. We thus propose a new research agenda of investigating representations to support the development and use of information and information technologies. This agenda remains cognizant and incorporates all issues related to conceptual modeling scripts, grammars, methods and context that Wand and Weber's framework stipulated, but is substantially broader as it explicitly recognizes the role of the conceptual modeling community in supporting a wide range of human interactions with information technologies. At the same time, it retains the core of the traditional framework, as the issue of representation constituted a major part of research on conceptual modeling scripts, grammars and methods (Browne and Parsons 2012; Burton-Jones and Grange 2013; Kent 1978; Rai 2017; Wand and Weber 1995). Figure 1 shows our view of this framework.

To illustrate the applicability of our new framework, consider several research directions that follow from it:

1. While Wand and Weber's framework was script-centric, our new framework does not insist on this emphasis, which makes it easier to accommodate emerging forms of representations. As the digital envelope expands, much of this process is spontaneous and highly creative, through which novel forms of representation are born. Thus, many successful systems (e.g., Facebook, Twitter) may not implement traditional modeling (e.g, ER diagrams) or use traditional storage technology (e.g., relational) and their successes paves way to novel modeling paradigms (e.g., agile modeling, noSQL databases). Many of these emerging systems explicitly proceed without a modeling script, or use modeling in a different way (e.g., for feasibility analysis or data interpretation) (Storey and Song 2017) . The new framework calls to investigate novel representational approaches and assumptions made when no script is involved (e.g., Kaur and Rani 2013; Lukyanenko and Parsons 2013).
2. While it remains important to study effective and appropriate representations to support development of new IS, with the growth of digital content, novel needs are emerging. Repurposing data for unanticipated insights is at the heart of the increasing growth of data mining, business analytics and applied artificial intelligence (Rai 2017; Chen, Chiang and Storey 2012). Here, representations remain critical,

but their role changes – they no longer guide IS development, but are needed to integrate, visualize and interpret massive volumes of heterogeneous data to make informed decisions. Further, different assumptions made when assembling information for the analytics process may result in different model performance and predictive power, and thus may result in different actions taken.

3. In moving beyond the conceptual modeling scripts, our new framework enables exciting new synergies between conceptual modeling research and other research streams that may be affected by the assumptions behind and the quality of the representations. This includes studies that investigate the impact of new representations by ordinary users on information quality, effective use, adoption and more generally IS success (Lukyanenko et al., 2014; Burton-Jones and Grange 2013; Lukyanenko and Parsons 2014).
4. As our new framework does not insist on the traditional modeling process, it supports the emerging practice of information production by ordinary people. Currently, very little is known about these more spontaneous kinds of models paving the way to an exciting new direction for the conceptual modeling research (Lukyanenko et al., 2017; Recker 2015).
5. Our new framework explicitly recognizes the need for ongoing design innovation in response to technological change. For example, the requirements of open information environments – where controls over information production are considerably weaker than in the traditional corporate settings, motivating the search for novel approaches to conceptual modeling that is more adaptable, flexible and open (Chen 2006; Liddle and Embley 2007; Parsons and Wand 2014). Likewise, the blooming practice of machine learning and business analytics may require new forms of representations of data.
6. The new framework proposes feedbacks as part of a research agenda. We explicitly recognize that antecedents could influence other antecedents. For example, ontological assumptions could influence grammars or creator's capabilities may influence the method employed in appropriating a grammar. Next, outcomes can have feedback loops to other outcomes. Using a representation for communication about a domain could lead to better domain understanding (Geiger 2010; Power 2011; Hoffer, Ramesh and Topi 2012; Anglim, Milton, Rajapakse and Weber 2009). Lastly, outcomes can also impact the antecedents to representations. For example, lack of effective use, adoption or quality could lead to a change in the creator's capabilities as the creator may learn or realize a better way to create future representations to mitigate the issues. Explicit modelling of feedback in the new framework should provide impetus for more research of this type.

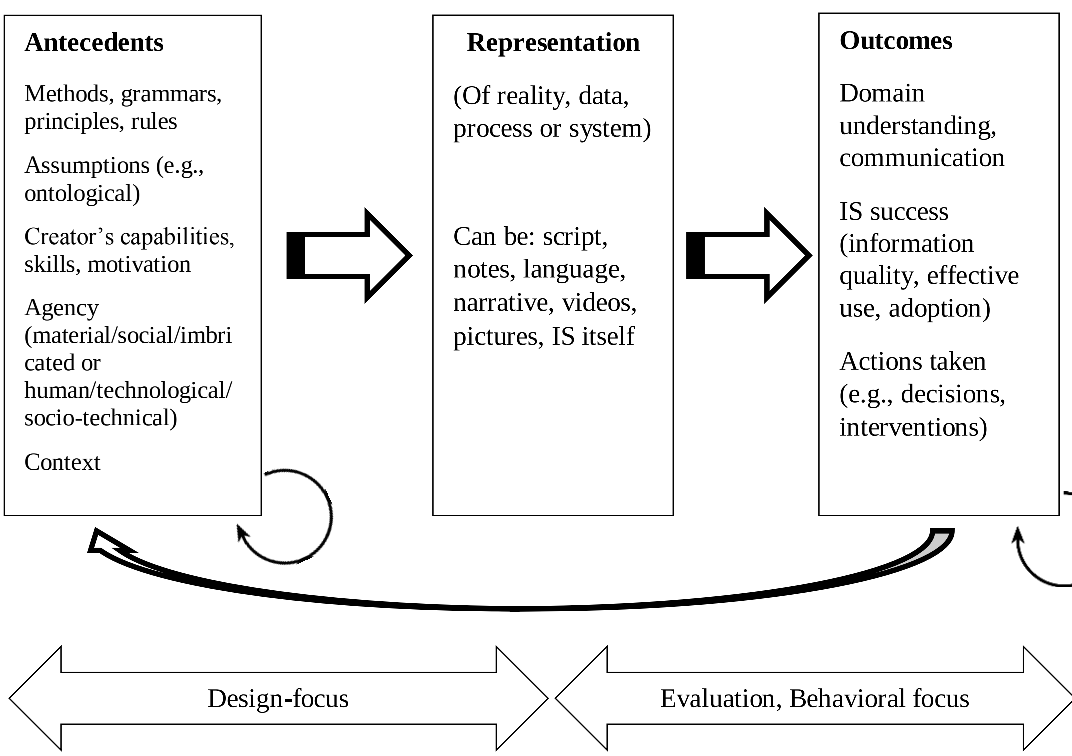

Figure 1. A New Research Framework to support future conceptual modeling research

CONCLUSION

Conceptual modeling as a research field has matured into an established research area of IS. Perhaps it is not as regarded in the same manner as research on technology adoption and business value of technology, but conceptual modeling stands as a cornerstone of the research discipline.

Yet, the standing and reputation of conceptual modeling within the discipline is not stable. As any other field, conceptual modeling research is rightfully under constant scrutiny in terms of its validity, applicability, relevance and utility in our ever-changing world. To cement the place as a research field within IS and surrounding disciplines, it will be important to constantly review and revise our own research efforts on conceptual modeling.

To that end, in this paper we have taken two important steps. We examined the influence and consequences of a seminal research framework in the field, and we provided a new research framework that we believe offers a reinvigorating and exciting new perspective on conceptual modeling research challenges and opportunities. In doing so, we have created new pathways to research on conceptual modeling that (a) both relax and challenge our own assumptions about what conceptual modeling is, and (b) move our research efforts towards the fringes of the conceptual modeling paradigm, to areas where we are required to explore unknown territory rather than confirm known principles. Our new framework makes an important step in this direction by drawing attention to significant new opportunities for the conceptual modeling community and substantially expanding our view of what counts as conceptual modeling research. It also stands to bring different research communities that deal with digital representations (e.g. information quality and conceptual modeling) into closer contact promising more opportunities for cross-pollination of ideas and interdisciplinary collaboration. Our new framework strongly suggests that conceptual modeling research is impacted by and impacts a broad range of issues related to information and information technology.

In following the agenda set by our work, we may find out that conceptual modeling has its limits. But we will for certain increase our confidence in where, how and why conceptual modeling is effective and useful – and we may discover that conceptual modeling has premises and promises that we are yet to foresee.

REFERENCES

[1] Y. Wand, R. Weber, Research commentary: information systems and conceptual modeling—a research agenda, Information Systems Research, 13 (2002) 363-376.

[2] J. Webster, R.T. Watson, Analyzing the past to prepare for the future: Writing a literature review, MIS Quarterly, 26 (2002) xiii-xxiii.

[3] G. Paré, M.-C. Trudel, M. Jaana, S. Kitsiou, Synthesizing information systems knowledge: A typology of literature reviews, Information & Management, 52 (2015) 183-199.

[4] F. Liu, M.D. Myers, An analysis of the AIS basket of top journals, Journal of systems and information technology, 13 (2011) 5-24.

[5] J. Recker, M. Rosemann, M. Indulska, P. Green, Business process modeling-a comparative analysis, Journal of the Association for Information Systems, 10 (2009) 333-363.

[6] G. Irwin, D. Turk, An ontological analysis of use case modeling grammar, Journal of the Association for Information Systems, 6 (2005) 1-36.

[7] P. Bera, A. Krasnoperova, Y. Wand, Using ontology languages for conceptual modeling, Journal of Database Management, 21 (2010) 1-28.

[8] G. Shanks, E. Tansley, J. Nuredini, D. Tobin, R. Weber, Representing part-whole relations in conceptual modeling: an empirical evaluation, MIS Quarterly, 32 (2008) 553-573.

[9] P.L. Bowen, R.A. O'Farrell, F.H. Rohde, An empirical investigation of end-user query development: the effects of improved model expressiveness vs. complexity, Information Systems Research, 20 (2009) 565-584.

[10] K. Figl, J. Mendling, M. Strembeck, The influence of notational deficiencies on process model comprehension, Journal of the Association for Information Systems, 14 (2012) 312-338.

[11] R. Clarke, A. Burton-Jones, R. Weber, On the Ontological Quality and Logical Quality of Conceptual-Modeling Grammars: The Need for a Dual Perspective, Information Systems Research, 27 (2016) 365-382.

[12] B. Dobing, J. Parsons, Dimensions of UML diagram use: a survey of practitioners, Journal of Database Management, 19 (2008) 1-18.

[13] J. Recker, Continued use of process modeling grammars: the impact of individual difference factors, European Journal of Information Systems, 19 (2010) 76-92.

[14] D. VanderMeer, K. Dutta, Applying learner-centered design principles to UML sequence diagrams, Journal of Database Management, 20 (2009) 25-47.

[15] G. Poels, A. Maes, F. Gailly, R. Paemeleire, The pragmatic quality of Resources- Events- Agents diagrams: an experimental evaluation, Information Systems Journal, 21 (2011) 63-89.

[16] G. Poels, Understanding business domain models: The effect of recognizing resource-event-agent conceptual modeling structures, Journal of Database Management, 22 (2011) 69-101.

[17] J. Parsons, Y. Wand, Using cognitive principles to guide classification in information systems modeling, MIS Quarterly, 30 (2008) 839-868.
[18] I. Hadar, P. Soffer, Variations in conceptual modeling: classification and ontological analysis, Journal of the Association for Information Systems, 7 (2006) 568-592.
[19] R. Lukyanenko, J. Parsons, Y.F. Wiersma, The IQ of the Crowd: Understanding and Improving Information Quality in Structured User-Generated Content, Information Systems Research, 25 (2014) 669-689.
[20] Y. An, X. Hu, I.-Y. Song, Maintaining mappings between conceptual models and relational schemas, Journal of Database Management, 21 (2010) 36-68.
[21] J. Pardillo, J.-N. Mazón, J. Trujillo, An MDA Approach and QVT Transformations for the Integrated Development of Goal-Oriented Data Warehouses and Data Marts, Journal of Database Management (JDM), 22 (2011) 43-68.
[22] J. Parsons, An experimental study of the effects of representing property precedence on the comprehension of conceptual schemas, Journal of the Association for Information Systems, 12 (2011) 401-422.
[23] P.L. Bowen, R.A. O'Farrell, F.H. Rohde, Analysis of competing data structures: Does ontological clarity produce better end user query performance, Journal of the Association for Information Systems, 7 (2006) 514-544.
[24] P. Bera, A. Burton-Jones, Y. Wand, How Semantics and Pragmatics Interact in Understanding Conceptual Models, Information Systems Research, 25 (2014) 401-419.
[25] V. Khatri, I. Vessey, V. Ramesh, P. Clay, S.-J. Park, Understanding conceptual schemas: Exploring the role of application and IS domain knowledge, Information Systems Research, 17 (2006) 81-99.
[26] A. Burton-Jones, P.N. Meso, The effects of decomposition quality and multiple forms of information on novices' understanding of a domain from a conceptual model, Journal of the Association for Information Systems, 9 (2008) 748-802.
[27] P. Bera, Analyzing the Cognitive Difficulties for Developing and Using UML Class Diagrams for Domain Understanding, Journal of Database Management, 23 (2012) 1-29.
[28] K. Siau, Informational and computational equivalence in comparing information modeling methods, Journal of Database Management, 15 (2004) 73-86.
[29] J. Krogstie, G. Sindre, H. Jørgensen, Process models representing knowledge for action: a revised quality framework, European Journal of Information Systems, 15 (2006) 91-102.
[30] A. Gemino, D. Parker, Use case diagrams in support of use case modeling: Deriving understanding from the picture, Journal of Database Management, 20 (2009) 1-24.
[31] S. Purao, V.C. Storey, T. Han, Improving analysis pattern reuse in conceptual design: Augmenting automated processes with supervised learning, Information Systems Research, 14 (2003) 269-290.
[32] A. Koschmider, M. Song, H.A. Reijers, Social software for business process modeling, Journal of Information Technology, 25 (2010) 308-322.
[33] P. Loucopoulos, W. Kadir, BROOD: business rules-driven object oriented design, Journal of Database Management, 19 (2008) 41-73.
[34] M. Davern, T. Shaft, D. Te'eni, Cognition matters: Enduring questions in cognitive IS research, Journal of the Association for Information Systems, 13 (2012) 273-314.
[35] G.J. Browne, J. Parsons, More Enduring Questions in Cognitive IS Research, Journal of the Association for Information Systems, 13 (2012) 1000-1011.
[36] W. Bandara, G.G. Gable, M. Rosemann, Factors and measures of business process modelling: model building through a multiple case study, European Journal of Information Systems, 14 (2005) 347-360.
[37] P. Green, M. Rosemann, Applying ontologies to business and systems modelling techniques and perspectives: Lessons learned, Journal of Database Management, 15 (2004) 105-117.
[38] J. Recker, M. Indulska, M. Rosemann, P. Green, The ontological deficiencies of process modeling in practice, European Journal of Information Systems, 19 (2010) 501-525.
[39] J. Recker, "Modeling with tools is easier, believe me"—The effects of tool functionality on modeling grammar usage beliefs, Information Systems, 37 (2012) 213-226.
[40] P. Soffer, I. Hadar, Applying ontology-based rules to conceptual modeling: a reflection on modeling decision making, European Journal of Information Systems, 16 (2007) 599-611.
[41] T.J. Larsen, F. Niederman, M. Limayem, J. Chan, The role of modelling in achieving information systems success: UML to the rescue?, Information Systems Journal, 19 (2009) 83-117.
[42] H. Zhang, L. Liu, T. Li, Designing IT systems according to environmental settings: A strategic analysis framework, The Journal of Strategic Information Systems, 20 (2011) 80-95.
[43] J. Trujillo, S. Luján-Mora, I.-Y. Song, Applying UML and XML for designing and interchanging information for data warehouses and OLAP applications, Journal of Database Management, 15 (2004) 41-72.
[44] I. Garrigós, J. Pardillo, J.-N. Mazón, J. Zubcoff, J. Trujillo, R. Romero, A Conceptual modeling personalization framework for OLAP, Journal of Database Management, 23 (2012) 1-16.
[45] C.E.H. Chua, V.C. Storey, R.H. Chiang, Knowledge representation: a conceptual modeling approach, Journal of Database Management, 23 (2012) 1-30.

[46] F. Fonseca, J. Martin, Learning the differences between ontologies and conceptual schemas through ontology-driven information systems, Journal of the Association for Information Systems, 8 (2007) 129-142.
[47] E. Fernández-Medina, J. Trujillo, M. Piattini, Model-driven multidimensional modeling of secure data warehouses, European Journal of Information Systems, 16 (2007) 374-389.
[48] F. D'aubeterre, R. Singh, L. Iyer, Secure activity resource coordination: empirical evidence of enhanced security awareness in designing secure business processes, European Journal of Information Systems, 17 (2008) 528-542.
[49] A. Dreiling, M. Rosemann, W. Van Der Aalst, L. Heuser, K. Schulz, Model-based software configuration: patterns and languages, European Journal of Information Systems, 15 (2006) 583-600.
[50] N.M. Vergara, J.M.T. Linero, A.V. Moreno, Model-driven component adaptation in the context of Web Engineering, European Journal of Information Systems, 16 (2007) 448-459.
[51] R. Lukyanenko, J. Parsons, Y.F. Wiersma, G. Wachinger, B. Huber, R. Meldt, Guidelines for Conceptual Modeling of User-generated Content, Journal of the Association for Information Systems 18 (2017) forthcoming.
[52] H.C. Chang, A new perspective on Twitter hashtag use: Diffusion of innovation theory, Proceedings of the American Society for Information Science and Technology, 47 (2010) 1-4.
[53] V. Ramesh, G.J. Browne, Expressing casual relationships in conceptual database schemas, Journal of Systems and Software, 45 (1999) 225-232.
[54] J. Erickson, K. Lyytinen, K. Siau, Agile modeling, agile software development, and extreme programming: the state of research, Journal of database Management, 16 (2005) 88-100.
[55] R. Lukyanenko, J. Parsons, B. Samuel, Do We Need an Instance-Based Conceptual Modeling Grammar?, in: Symposium on Research in Systems Analysis and Design (AIS SIGSAND 2015), 2015.
[56] W.J. Orlikowski, CASE tools as organizational change: Investigating incremental and radical changes in systems development, MIS quarterly, 17 (1993) 309-340.
[57] W.M.P. van der Aalst, Process Mining Discovery, Conformance and Enhancement of Business Processes, Heidelberg, Germany: Springer, 2011.
[58] O. Akhigbe, L. Lessard, Situating requirements engineering methods within design science research, in: Breakthroughs and Emerging Insights from Ongoing Design Science Projects: Research-in-progress papers and poster presentations from the 11th International Conference on Design Science Research in Information Systems and Technology (DESRIST) 2016. St. John, Canada, 23-25 May, DESRIST 2016, 2016.
[59] M.K. Sein, O. Henfridsson, S. Purao, M. Rossi, R. Lindgren, Action design research, MIS quarterly, (2011) 37-56.
[60] P.M. Leonardi, When flexible routines meet flexible technologies: Affordance, constraint, and the imbrication of human and material agencies, MIS Quarterly, 30 (2011) 147-167.
[61] J. Zhang, The Nature of External Representations in Problem Solving, Cognitive Science, 21 (1997) 179-217.
[62] L. Floridi, The road to the philosophy of information, in: Luciano Floridi's Philosophy of Technology, Springer, 2012, pp. 245-271.
[63] P. Hoyningen-Huene, Systematicity: The nature of science, Oxford University Press, Oxford, UK, 2013.
[64] A. Burton-Jones, C. Grange, From use to effective use: A representation theory perspective, Information Systems Research, 24 (2013) 632-658.
[65] W. Kent, Data and Reality: Basic assumptions in data processing reconsidered, 211p, North-Holland Pub. Co., North-Holland, Amsterdam, 1978.
[66] A. Rai, Diversity of design science contributions, MIS Quarterly, 41 (2017) iii–xviii.
[67] Y. Wand, R. Weber, On the deep structure of information systems, Information Systems Journal, 5 (1995) 203-223.
[68] V.C. Storey, I.-Y. Song, Big data technologies and management:What conceptual modeling can do, Data & Knowledge Engineering, (2017).
[69] K. Kaur, R. Rani, Modeling and querying data in NoSQL databases, in: 2013 IEEE International Conference on Big Data, 2013, pp. 1-7.
[70] R. Lukyanenko, J. Parsons, Is traditional conceptual modeling becoming obsolete?, in: International Conference on Conceptual Modeling, Springer, 2013, pp. 61-73.
[71] H. Chen, R.H. Chiang, V.C. Storey, Business intelligence and analytics: From big data to big impact, MIS quarterly, 36 (2012) 1165-1188.
[72] R. Lukyanenko, J. Parsons, Using Field Experimentation to Understand Information Quality in User-generated Content, in: CodeCon@MIT, 2014.
[73] J. Recker, Research on conceptual modelling: less known knowns and more unknown unknowns, please, in: 11th Asia-Pacific Conference on Conceptual Modelling, Australian Computer Society, 2015, pp. 3-7.
[74] P.P. Chen, Suggested research directions for a new frontier–active conceptual modeling, in: International Conference on Conceptual Modeling, Springer, 2006, pp. 1-4.
[75] S.W. Liddle, D.W. Embley, A common core for active conceptual modeling for learning from surprises, in: International Workshop on Active Conceptual Modeling of Learning, Springer, 2007, pp. 47-56.
[76] J. Parsons, Y. Wand, A foundation for open information environments, in: European Conference on Information Systems, Tel Aviv, Israel, 2014.

[77] J. Geiger, Why Do We Model?, Information Management (1521-2912), 20 (2010) 32-33.
[78] D.A.N. Power, Data Modeling: The Lingua Franca of a Successful MDM Effort, Information Management (1521-2912), 21 (2011) 28-29.
[79] J.A. Hoffer, V. Ramesh, H. Topi, Modern Database Management, 11th ed., Prentice Hall, Boston, MA, 2012.
[80] B. Anglim, S.K. Milton, J. Rajapakse, R. Weber, Current trends and future directions in the practice of high-level data modeling: An empirical study, in: ECIS, 2009, pp. 122-133.