Conceptual Modeling in Digital Transformations – Enabling enterprise design dialogues

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Abstract

Conceptual models are both foundational in, and part of, the broader practice of domain modeling. In general, conceptual models are useful in dealing head-on with many types of knowledge-intensive efforts to describe and reason about the conceptual structures of a domain of interest.

In the context of digital transformations, conceptual models have an important role to play in (collaboratively) capturing the understanding of relevant aspects of the existing/desired enterprises and their context. At the same time, digital transformations also bring about many important challenges for conceptual modeling. In this paper, we identify two related challenges in this context, concerning the need to manage the diversity of the involved participants, as well as the need to enable the inclusion of non-experts in the modeling activities. For each of these challenges we will also suggest directions for future research. In doing so, we also argue that, in this context, it is important to understand conceptual modeling as being an integral part of what we call *enterprise design dialogues* that occur naturally across the enterprise.

Keywords

Conceptual Modeling, Digital Transformation, Enterprise Design Dialogues

1. Introduction

Whenever we, as humans, have a need to (jointly) reason/reflect about some part of an existing/imagined domain, we essentially use models to express our understanding of this (part of the) domain [1]; i.e. *domain* models. In line with Proper and Guizzardi [2], we consider *conceptual models* to be a specific class of domain models, "where the purpose of the model is dominated by the ambition to remain as-true-as-possible to the *conceptualization of the domain by the collective agent*." The *conceptualization of the domain by the collective agent* refers to the (shared)

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understanding[1] of the domain, as harbored in the mind(s) of the participants in a modeling creation/usage process. Conceptual models can be used to explicitly capture (descriptive and/or prescriptive) domain knowledge; they allow us to clarify and understand the things we talk about, and reason about, at a chosen level of abstraction and from some specific perspective. In the remainder of this paper, we will use the term *conceptual modeling* to refer to all activities involved in the creation, management, and usage of conceptual models.

Over the last three decades, the use of various forms of conceptual modeling has widened due to mutually strengthening developments. The fast growth of the Internet of Things (IoT) and the Big Data phenomenon have made management and control of meaning in data/information/knowledge exchange, an equally fast growing challenge. Starting from the field and practice of database and information system design conceptual modeling has extended into internet-related system design, prominently involving fields like information retrieval, text mining and knowledge extraction, and in general it has become an instrument in controlling semantics in applications of data science, machine learning, and AI [4]. In the rapidly growing application of sub-symbolic AI and data science techniques, conceptual modeling plays a role not only in sorting out and controlling data meaning at the source and throughout data processing pipelines, but also in achieving required *explainability* of decisions made by algorithms [5], and in blending human and machine decisions (augmented or hybrid intelligence [6]). This is particularly true for cases where an AI system makes autonomous decisions that deeply impact the lives of human beings – e.g. in the case of assessing insurance claims or deciding on legal matters.

Furthermore, as a result of the increased role of data, leading to the so-called *data driven* enterprises, conceptual modeling has also found its way towards data management and governance practices and support [7].

Finally, conceptual modeling has to some extent also integrated a number of previously rather separate directions in semantic modeling, including 'classic' entity-relationship modeling, fact-based modeling, UML-style class modeling, Semantic Web-oriented RDF and OWL modeling (ontologies), and arguably also linguistic modeling (Wordnet, NLP resources) [4, 8].

In general, conceptual models are useful in dealing head-on with many types of knowledge-intensive efforts to describe and reason about the conceptual structure of a domain of interest. In this paper, we focus on the role of conceptual modeling in the context of digital transformations, where we consider digital transformations as *deliberate efforts to transform the architecture of the organization with a major impact on its digital capabilities* [9].

In the context of digital transformations, conceptual models have an important role to play in (collaboratively) capturing the understanding of relevant aspects of the existing/desired enterprises and their context. At the same time, digital transformations also bring about many important challenges for conceptual modeling.

In this paper, we identify two related challenges in this regard, which center on the need to manage the diversity of the involved stakeholders, as well as the need to enable the inclusion of non-experts in the modeling activities. In discussing each of these challenges we will also suggest directions for future research. In doing so, we also argue that, in this context, it is important to understand conceptual modeling as being an integral part of what we call *enterprise*

[1] Following the semantic triangle [3]; see Proper and Guizzardi [2, 1] for a deeper explanation.

design dialogues that occur naturally across the enterprise, and that such dialogues do not only take place in the context of top-down driven development/transformation activities.

In line with this, the remainder of this paper is structured as follows. We start in section 2 with a discussion of the role of conceptual modeling in the context of digital transformation. Based on this, section 3 then discusses the need to embrace and managing the diversity of the involved participants and their domain understandings. In doing so, we will also discuss the need to understand conceptual modeling in this context as being an integral part of what we call *enterprise design dialogues*. This, then also leads to section 4, where we discuss the challenge of inclusion of non-experts in modeling.

2. Conceptual Modeling in Digital Transformations

In the context of digital transformations, conceptual models may capture different aspects of an enterprise; resulting in enterprise models. These enterprise models may be concerned with the enterprise's value proposition(s), business processes, information processing, business rules, application landscapes, etc. These models are used widely in the context of the design, development and interconnecting of a wide range of information systems, including digital twins and advanced rule-based systems (for example, for Tax Law Execution, [10, 11]). As highlighted in [12], in the context of digital transformations, conceptual/domain models can be used towards a variety of high level purposes, including to aim to *understand*, to *assess*, to *diagnose*, to *design*, to *develop*, to *operate* or to *regulate* (parts of) an enterprise.

As discussed above, conceptual models aim to remain as-true-as-possible to the original conceptualization of the domain that is modeled. However, depending on the context, conceptual models may be complemented with models that incorporate 'conceptual compromises' [2, 13] which, for instance, enable animation, simulation, execution, gamification, or automated (logic-based) reasoning. In [13] it is suggested to refer to these models as *utility-design models*, as these models include 'conceptual compromises' in favor of some intended utilization of the model.

We should also beware that, in practice, the use of conceptual models often goes unnoticed since the involved models do not always take the form of traditional 'boxes and lines' diagrams or some other dedicated notation. They may also take the form of, or be embodied in, control panels of e.g. industrial processes, (structured) text documents/wikis, or even spreadsheets. People might not even refer to these artifacts as being/reflecting (conceptual) models; to them they are tools to get the job done. This also resonates well with the observation of Junginger [14]: "Naturally, [engineers] are looking for forms and practices of design they are familiar with."

Though the involved conceptual modeling techniques and methods and their specific uses differ substantially, they all play a role in pragmatic activities for managing and controlling concept semantics as part of digital transformation. Also, they are all based, to some extent, on natural language semantics, but harnessed through more or less strict, formal or semi-formal structures and constraints stemming from logic, set theory, knowledge engineering, and computer science in general. In principle, this is good news for conceptual modeling and will propel it and its use forward, even if this involves an increasing variety of forms and uses.

At the same time, from a practical point of view, we see two important, interrelated challenges

that need answering. There are many more, but these are the ones we choose to focus on in the remainder, also in view of their direct relevance to the evolving practice of conceptual modeling. The two challenges we focus on center on the need to manage the diversity of the involved participants, as well as the need to enable the inclusion of non-experts in the modeling activities.

3. Embracing and Managing Diversity

Digital transformations typically involve many stakeholders [15, 16] with differing stakes and interests, who (should) influence the direction and/or speed of the transformation. As a result, conceptual modeling in the context of digital transformation needs to embrace this diversity of perspectives and stakeholders. In addition, managing and embracing this diversity is paramount because conceptual models traditionally form the base for the creation/configuration of 'digital actors' (such as automated information systems).

Even more, digital transformations will not only involve top-down driven decision making and projects. They will also involve numerous change made in the operational processes of the enterprise, resulting in bottom-up changes as well.

As such, we take the view that the design of the structure (processes, hierarchies, (IT) infrastructures) of an enterprise is (re)shaped by a continuous flow of (top-down and bottom-up) *enterprise design dialogues* between the different involved human actors. Or in the words of Junginger [14]: "Design literally shapes organizational reality." This may sound abstract, but in practice, such design dialogues occur all across enterprises. Each time co-workers discuss 'how to' divide work, or conduct a (new) task, they essentially engage in an enterprise design dialogue. When process engineers discuss with senior business management how to shape a business process, they are having a design dialogue. When database engineers discuss with domain experts what information needs to be captured in the database, they are having a design dialogue. When an enterprise architect interacts with different stakeholders to arrive at a new version of the enterprise architecture, they are having a design dialogue. These examples show how design dialogues occur across an enterprise, meanwhile (re)shaping the design of the enterprise.

The notion of *enterprise design dialogue* also intends to reflect notions such as authoring "authoring of organizations" [17], as well as views from organizational design [18]. It also acknowledges the fact that an enterprise is certainly not a 'machine' (in the sense of [19] Images of Organization) that can be 'engineered' as such. We do, however, assume that these dialogues use and/or result in some artifact that represents some abstraction of some aspect(s) of the design of the enterprise; i.e. some (conceptual) enterprise model.

Enterprise design dialogue may occur bottom-up, but they may also take place as part of an orchestrated enterprise development/transformation process. In the latter case, one may explicitly develop a conversation strategy [20], spanning multiple design dialogues. As suggested in [20], the different steps (i.e. distinct design dialogues) involved in a conversation strategy can serve more specific goals with regards to 'enterprise knowledge', such as: *share* (or create) knowledge, *agree to* the shared knowledge, *commit* to the consequences/actions resulting from the shared/created knowledge.

Underlying the goals to share, create, agree to and commit to knowledge, there is a direct

communicative need to ensure a shared understanding, among the different involved participants (and their background [21, 22]). In the context of enterprise design dialogues with a high variety of participants, these conceptual models play the role of *boundary objects* [23, 24], and are as such the cornerstones for the creation of joint understanding.

As a consequence, describing and controlling the semantics (and to some extent also the syntax) of key concepts used in conceptual models, in specific situations/contexts, while wielding one or more specific perspectives, thus also plays an unavoidable and foundational role in digital transformation [25]. This includes the need to achieving agreement on (if not negotiation of [26]) concepts and models, and making them traceable (*Where and who do they come from? What are they based on? What use and perspective are they intended for?*).

One of the promises of conceptual modeling that scholars and professionals frequently list is standardization of language. This is harder than it sounds [27]. Language is very close to the core of who we are, and often not easy to influence or change. Think of local dialects in geographical regions and figures of speech in different organizations/communities.

Many approaches to conceptual modeling emphasize the need to 'standardize' but fail to mention what the scope of standardization efforts should be. It appears that it is often assumed that language (i.e. concepts and their definitions) should be standardized across the organization, much to the frustration of professionals who simply "want to do their work with effective ICT support" [28]. An exception to the 'the whole organization' rule can be found in domain driven design [29]. This (design) theory is becoming increasingly popular again [30]. A core thought behind these theories is to use conceptualization in a much smaller local 'domain' and worry about the interfaces (translations) later.

In summary, in managing the diversity of the actors involved in enterprise design dialogues, and associated modeling activities in particular, we suggest the following three main avenues for further research:

1. *Conversation strategies* – The concept of conversation strategies, as coined in [20], can be extended. Both in terms of more explicit heuristics on how to deal with diversity, as well as also positioning bottom-up conversations to deal with bottom-up/emergent changes in enterprises.
2. *Models as boundary objects* – The further elaboration of the role of models as boundary objects [23, 24], in particular in terms of the understandings of the used modeling concepts/constructs by the different actors [21, 22].
3. *Negotiation and evolution of modeling concepts* – Enabling more explicit negotiation [26], and evolution [27, 28], of (domain specific) modeling concepts/constructs used to express models, especially in the case of models that bridge between different communities and domains [25].

4. Inclusion of Non-experts in Modeling

Due to the diversity of the actors that need to be involved in conceptual modeling in the context of digital transformation, there is an immediate need to also engage *non-experts* in modeling. Echoing our own earlier work on more natural forms of modeling [31, 32], Sandkuhl et al. [33] also observed how modeling increasingly becomes embedded in everyday work.

In the 'digital era', the range of different participants involved grows even further, since 'digital actors' will increasingly become active participants in the modeling processes as well. The increase of the number, and diversity, of the participants involved in conceptual modeling causes a 'modeling bottleneck' in the sense that there is growing lack of modeling skills.

At the same time, we should also acknowledge that, in principle, modeling is quite natural for humans. We started this paper with the observation that "Whenever we, as humans, have a need to (jointly) reason/reflect about some part of an existing/imagined domain, we essentially use models to express our understanding of this (part of the) domain". However, even though modeling is a natural thing for humans to do, actually doing so in terms of e.g. UML, BPMN or ArchiMate is not so natural for most humans. In a real world context of enterprises, in particular when dealing with ideation, re-designing, sense-making, etc., we also see many other forms of modeling being used, including the proverbial 'sketch on the back of a napkin'. This, once more, stresses the point that when considering (conceptual) models, we should not be framed by 'boxes-and-lines' thinking. For instance, the aforementioned strategies for more natural modeling [31, 32] suggest to use tangible objects/shapes (spoons, sugar cubes, plates, etc) during modeling.

It is important to note that the question of how natural modeling is for a human in general vs. how natural it is to do so in terms of languages such as UML or ArchiMate, is largely orthogonal to the distinction of a *conceptual models* and *utility design models*.

Underlying this, there is a trade-off related to the Return on Modeling Effort (RoME) [34] and the value of modeling [35]. The creation, administration, and use of (conceptual) domain models requires investments in terms of time, money, cognitive effort, learning, etc. Such investments should be met by a (potential) return, which is ultimately rooted in the *purpose* of the model [36, 37].

Depending on the purpose of a conceptual model, there may be a need to go beyond a 'sketch on the back of a napkin', and e.g. produce a precise BPMN model. This need should then also warrant the effort for the actors involved (and budget owners) to (a) understand the domain to be modeled, (b) possibly learn the BPMN language and an associated modeling tool, and (c) express the domain understanding in terms of a BPMN model with the chosen modeling tool.

To deal with the 'modeling bottleneck', and to reduce the *effort* (the *E* of *RoME*), we suggest to digitally transform modeling itself [38, 39, 40]. In other words, capitalize on advances and technologies, such as machine learning, data mining, recommender systems, chat-bots, etc, to empower people without particular modeling background to produce higher quality domain models. Our hypothesis is that this will create better conceptual models and that the impact on the time it takes to create these models is reduced. Results suggest that *assisted* modeling can indeed be useful, at least for novice modelers: assisted, in this context, means guiding the modeler through a series of steps that helps reduce the cognitive load in each step. The authors of [33] suggest to use the term *assistive technologies* to refer to the use of such technologies to support (domain) modeling, resulting in the notion of *assisted domain modeling* [40].

A concrete example of *assisted domain modeling*, is the strategy as proposed in [41], which suggest to treat (part of) the modeling task(s) as the selection of interpretation [41], starting from unspecific concepts and relations and then step-wise interpreting them in terms of the meta-model of the 'target' modeling language. In [42] an illustration of this strategy was provided, involving a case where 3rd year bachelor students are taught ArchiMate. In doing so,

the students were asked to first create a conceptualization using sticky notes on brown paper, then adorn these sticky notes with icons referring to the ArchiMate symbols, and then convert this to an actual ArchiMate model using the Archi modeling tool[2].

In general, a transition to *assisted (domain) modeling* suggests to employ a continuum of approaches stretching from automated 'concept mining' in a domain to 'assisted domain modeling' actively involving (non-modeling-expert) domain representatives. This includes approaches combining advanced automated techniques with assisted (guided) domain modeling by domain representatives [40].

Making the modeling process more engaging, by means of gamification [43, 44], the use of tangible objects in modeling activities [31, 32] and/or making use of concepts from crowdsourcing [8]. Currently, a major Dutch bank is involved in experimenting with the latter. Tangible objects also have a potential role to play here, as experience shows them e.g. to have an engaging effect on stakeholders during decision making [45, 46].

In summary, in including non-experts in modeling, we suggest the following three main avenues for further research:

1. *Strategies for natural modeling* – Making modeling more natural by e.g. allowing different forms of model representations (beyond boxes-and-lines), including the use of the aforementioned tangible objects [31, 32].
2. *Assisted modeling* – Provide more guidance for modeling tasks, essentially turning modeling processes into a hybrid mix of human, symbolic-AI and sub-symbolic AI [40].
3. *Engaging modelers* – Making the modeling process more engaging, by e.g. using gamification [43, 44], making use of concepts from crowdsourcing [8], or using tangible objects [45, 46].

5. Conclusion

This paper started with the observation that conceptual models are both foundational in, and part of, the broader practice of domain modeling. We then zoomed in on their role in the context of digital transformations, where they have an important role to play in (collaboratively) capturing the understanding of relevant aspects of the existing/desired enterprises and their context.

At the same time, digital transformations also bring about many important challenges for conceptual modeling. In this paper, we highlighted two related challenges for conceptual modeling in the context of digital transformations: the need to manage the diversity of the involved participants, as well as the need to enable the inclusion of non-experts in the modeling activities. For each of these challenges, we explored some of the background, while also listing the main avenues for future research to meet these challenges. Important in this is to understand the conceptual modeling activities in this context as being an integral part of what we call *enterprise design dialogues*, and that such dialogues do not only take place in the context of top-down driven development activities.

[2]In our current teaching practices, we actually use Miro for the initial steps

References

[1] H. A. Proper, G. Guizzardi, On Domain Conceptualization, in: D. Aveiro, G. Guizzardi, R. Pergl, H. A. Proper (Eds.), Advances in Enterprise Engineering XIV – 10th Enterprise Engineering Working Conference, EEWC 2020, Bozen-Bolzano, Italy, September 28, October 19, and November 9-10, 2020, Revised Selected Papers, volume 411 of *Lecture Notes in Business Information Processing*, Springer, Heidelberg, Germany, 2021, pp. 49–69. doi:10.1007/978-3-030-74196-9_4.

[2] H. A. Proper, G. Guizzardi, On Domain Modelling and Requisite Variety – Current state of an ongoing journey, in: J. Grabis, D. Bork (Eds.), The Practice of Enterprise Modeling. PoEM 2020, volume 400 of *Lecture Notes in Business Information Processing*, Springer, Heidelberg, Germany, Riga, Latvia, 2020, pp. 186–196. doi:10.1007/978-3-030-63479-7_13.

[3] C. W. Morris, Foundation of the Theory of Signs, in: International Encyclopedia of Unified Science, volume 1, 1928.

[4] P. Alexopoulos, Semantic Modeling for Data, Sebastopol, California: O'Reilly, 2020.

[5] S. Spreeuwenberg, AIX: Artificial Intelligence needs explanation, Amsterdam: LibRT, 2019.

[6] Z. Akata, D. Balliet, M. De Rijke, F. Dignum, V. Dignum, G. Eiben, A. Fokkens, D. Grossi, K. Hindriks, H. Hoos, et al., A research agenda for hybrid intelligence: augmenting human intellect with collaborative, adaptive, responsible, and explainable artificial intelligence, Computer 53 (2020) 18–28.

[7] B. v. Gils, Data Management: a gentle introduction – Balancing theory and practice, Van Haren Publishing, Zaltbommel, the Netherlands, 2020.

[8] T. Nobel, S. Hoppenbrouwers, J. Pleijsant, M. Ouborg, Word Meaning, Data Semantics, Crowdsourcing, and the BKM/A-Lex Approach, in: OTM Confederated International Conferences "On the Move to Meaningful Internet Systems", Berlin: Springer, 2019, pp. 67–78.

[9] B. v. Gils, H. A. Proper, Enterprise modelling in the age of digital transformation, in: R. A. Buchmann, D. Karagiannis, M. Kirikova (Eds.), The Practice of Enterprise Modeling – 11th IFIP WG 8.1. Working Conference, PoEM 2018, Vienna, Austria, October 31 – November 2, 2018, Proceedings, volume 335 of *Lecture Notes in Business Information Processing*, Springer, Heidelberg, Germany, 2018, pp. 257–273. doi:10.1007/978-3-030-02302-7_16.

[10] M. Corsius, S. Hoppenbrouwers, M. Lokin, E. Baars, G. Sangers-Van Cappellen, I. Wilmont, RegelSpraak: a CNL for executable tax rules specification, in: Proceedings of the Seventh International Workshop on Controlled Natural Language (CNL 2020/21), Special Interest Group on Controlled Natural Language, Amsterdam, Netherlands, 2021.

[11] A. Ausems, J. Bulles, M. Lokin, Wetsanalyse voor een werkbare uitvoering van wetgeving met ICT, the Hague: Boom, 2021.

[12] H. A. Proper, M. Bjeković, Fundamental challenges in systems modelling, in: H. C. Mayr, S. Rinderle-Ma, S. Strecker (Eds.), 40 Years EMISA 2019, May 15-17, 2019, Evangelische Akademie Tutzing, Germany, volume P-304 of *Lecture Notes in Informatics*, Gesellschaft für Informatik e.V., 2019, pp. 13–28. URL: https://dl.gi.de/20.500.12116/33130.

[13] H. A. Proper, On Model-Based Coordination of Change in Organizations, Springer, Heidelberg, Germany, 2021, pp. 79–98. doi:10.1007/978-3-030-84655-8_6.

[14] S. Junginger, Organizational Design Legacies & Service Design, Design Journal (2015).

Special Issue: Emerging Issues in Service Design.
[15] M. Op 't Land, H. A. Proper, M. Waage, J. Cloo, C. Steghuis, Enterprise Architecture – Creating Value by Informed Governance, The Enterprise Engineering Series, Springer, Heidelberg, Germany, 2008. doi:10.1007/978-3-540-85232-2.
[16] R. Wagter, H. A. Proper, Involving the right stakeholders – Enterprise coherence governance, in: H. A. Proper, R. Winter, S. Aier, S. d. Kinderen (Eds.), Architectural Coordination of Enterprise Transformation, The Enterprise Engineering Series, Springer, Heidelberg, Germany, 2018, pp. 99–110. doi:10.1007/978-3-319-69584-6.
[17] J. R. Taylor, The Communicational Basis of Organization: Between the Conversation and the Text, Communication Theory 6 (1996) 1–39.
[18] R. Magalhães (Ed.), Organization Design and Engineering: Coexistence, Cooperation or Integration, Palgrave-Macmillan, London, UK, 2014.
[19] G. Morgan, Images of Organization, Sage Publications, London, United Kingdom, 1998.
[20] H. A. Proper, S. J. B. A. Hoppenbrouwers, G. E. Veldhuijzen van Zanten, Communication of enterprise architectures, in: Enterprise Architecture at Work – Modelling, Communication and Analysis, The Enterprise Engineering Series, 4th ed., Springer, Heidelberg, Germany, 2017, pp. 59–72. doi:10.1007/978-3-662-53933-0_4.
[21] S. J. B. A. Hoppenbrouwers, W. Stokkum, M. E. Iacob, I. Wilmont, D. J. T. v. d. Linden, C. Amrit, M. Joosen, Stakeholder Communication, in: M. M. Lankhorst (Ed.), Agile Service Development, The Enterprise Engineering Series, Springer, Heidelberg, Germany, 2012, pp. 141–176. doi:10.1007/978-3-642-28188-4_7.
[22] D. J. T. v. d. Linden, S. J. B. A. Hoppenbrouwers, H. A. Proper, On the identification of modeler communities, International Journal of Information Systems Modeling and Design (2014) 22–40. doi:10.4018/ijismd.2014040102.
[23] R. Abraham, H. Niemietz, S. d. Kinderen, S. Aier, Can boundary objects mitigate communication defects in enterprise transformation? Findings from expert interviews, in: R. Jung, M. Reichert (Eds.), Proceedings of the 5th International Workshop on Enterprise Modelling and Information Systems Architectures, EMISA 2013, St. Gallen, Switzerland, September 5-6, 2013, volume 222 of *Lecture Notes in Informatics*, Gesellschaft für Informatik, Bonn, Germany, 2013, pp. 27–40. URL: https://dl.gi.de/handle/20.500.12116/17238.
[24] R. Abraham, Enterprise Architecture Artifacts As Boundary Objects – A Framework Of Properties, in: Proceedings of the 21st European Conference on Information Systems (ECIS 2013), Utrecht, the Netherlands, 2013. URL: http://aisel.aisnet.org/ecis2013_cr/120/.
[25] S. J. B. A. Hoppenbrouwers, A. I. Bleeker, H. A. Proper, Facing the Conceptual Complexities in Business Domain Modeling, Computing Letters 1 (2005) 59–68.
[26] P. Rittgen, Negotiating models, in: Proceedings of the 19th International Conference on Advanced Information Systems Engineering, CAiSE 2007, Trondheim, Norway, June 11-15, 2007, 2007, pp. 561–573.
[27] M. Bjeković, H. A. Proper, J.-S. Sottet, Embracing pragmatics, in: E. S. K. Yu, G. Dobbie, M. Jarke, S. Purao (Eds.), Conceptual Modeling – 33rd International Conference, ER 2014, Atlanta, GA, USA, October 27-29, 2014. Proceedings, volume 8824 of *Lecture Notes in Computer Science*, Springer, Heidelberg, Germany, 2014, pp. 431–444. doi:10.1007/978-3-319-12206-9_37.
[28] S. J. B. A. Hoppenbrouwers, Freezing Language; Conceptualisation processes in ICT

supported organisations, Ph.D. thesis, University of Nijmegen, Nijmegen, the Netherlands, 2003.
[29] E. J. Evans, Domain-Driven Design: Tackling Complexity in the Heart of Software, Addison Wesley, 2003.
[30] P. Strengholt, Data management at scale, best practices for enterprise architecture, O'Reilly, 2020.
[31] M. Bjeković, J.-S. Sottet, J.-M. Favre, H. A. Proper, A framework for natural enterprise modelling, in: IEEE 15th Conference on Business Informatics, CBI 2013, Vienna, Austria, July 15-18, 2013, IEEE Computer Society Press, Los Alamitos, California, 2013, pp. 79–84. doi:10.1109/CBI.2013.20.
[32] Z. Zarwin, M. Bjeković, J.-M. Favre, J.-S. Sottet, H. A. Proper, Natural modelling, Journal Of Object Technology 13 (2014) 4: 1–36. doi:10.5381/jot.2014.13.3.a4.
[33] K. Sandkuhl, H.-G. Fill, S. J. B. A. Hoppenbrouwers, J. Krogstie, F. Matthes, A. L. Opdahl, G. Schwabe, Ö. Uludag, R. Winter, From Expert Discipline to Common Practice: A Vision and Research Agenda for Extending the Reach of Enterprise Modeling, Business & Information Systems Engineering 60 (2018) 69—80. doi:10.1007/s12599-017-0516-y.
[34] M. Op 't Land, H. A. Proper, M. Waage, J. Cloo, C. Steghuis, The Results of Enterprise Architecting, in: [15], 2008. doi:10.1007/978-3-540-85232-2.
[35] G. Guizzardi, H. A. Proper, On Understanding the Value of Domain Modeling, in: G. Guizzardi, T. P. Sales, C. Griffo, M. Furnagalli (Eds.), Proceedings of 15th International Workshop on Value Modelling and Business Ontologies (VMBO 2021), Bolzano, Italy, 2021, volume 2835 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2021. URL: http://ceur-ws.org/Vol-2835/paper6.pdf.
[36] J. Rothenberg, The Nature of Modeling, in: L. E. Widman, K. A. Loparo, N. Nielson (Eds.), Artificial intelligence, simulation & modeling, John Wiley & Sons, New York, New York, 1989, pp. 75–92.
[37] B. Edmonds, C. Le Page, M. Bithell, E. Chattoe-Brown, V. Grimm, R. Meyer, C. Montañola Sales, P. Ormerod, H. Root, F. Squazzoni, Different modelling purposes, Journal of Artificial Societies and Social Simulation 22 (2019) 6. URL: http://jasss.soc.surrey.ac.uk/22/3/6.html. doi:10.18564/jasss.3993.
[38] M. Snoeck, J. Stirna, H. Weigand, H. A. Proper, Panel discussion: Artificial intelligence meets enterprise modelling (summary of panel discussion), volume 2586 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2019, pp. 88–97. URL: http://ceur-ws.org/Vol-2586/paper8.pdf.
[39] H. A. Proper, Digital Enterprise Modelling – Opportunities and Challenges, in: B. Roelens, W. Laurier, G. Poels, H. Weigand (Eds.), Proceedings of 14th International Workshop on Value Modelling and Business Ontologies, Brussels, Belgium, January 16-17, 2020, volume 2574 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2020, pp. 33–40. URL: http://ceur-ws.org/Vol-2574/short3.pdf.
[40] C. Feltus, Q. Ma, H. A. Proper, P. Kelsen, Towards AI Assisted Domain Modeling, in: I. Reinhartz-Berger, S. W. Sadiq (Eds.), Advances in Conceptual Modeling ER 2021 Workshops CoMoNoS, EmpER, CMLS, St. John's, NL, Canada, October 18-21, 2021, Proceedings, volume 13012 of *Lecture Notes in Computer Science*, Springer, Heidelberg, Germany, 2021.
[41] H. A. Proper, T. P. v. d. Weide, Modelling as selection of interpretation, in: H. C. Mayr, H. Breu (Eds.), Modellierung 2006, 22.-24. März 2006, Innsbruck, Tirol, Austria, Proceedings,

volume P82 of *Lecture Notes in Informatics*, Gesellschaft für Informatik, Bonn, Germany, 2006, pp. 223–232. URL: https://tinyurl.com/y3h4uas9.

[42] H. A. Proper, M. Bjeković, B. v. Gils, S. J. B. A. Hoppenbrouwers, Towards a Multi-Stage Strategy to Teach Enterprise Modelling, in: D. Aveiro, G. Guizzardi, S. Guerreiro, W. Guédria (Eds.), Advances in Enterprise Engineering XII – 8th Enterprise Engineering Working Conference, EEWC 2018, Luxembourg, May 28 – June 1, 2018, Proceedings, volume 334 of *Lecture Notes in Business Information Processing*, Springer, Heidelberg, Germany, 2018, pp. 181–202. doi:10.1007/978-3-030-06097-8.

[43] S. J. B. A. Hoppenbrouwers, P. J. F. Lucas, Attacking the knowledge acquisition bottleneck through games-for-modelling, in: Proceedings of the AI and Games Symposium at the AISB 2009 Convention (6-9 April 2009), Edinburgh, Scotland, Falmer, Brighton : The Society for the Study of Artificial Intelligence and the Simulation of Behaviour, 2007, pp. 81–86.

[44] J. Groenewegen, S. J. B. A. Hoppenbrouwers, H. A. Proper, Playing ArchiMate models, in: I. Bider, T. A. Halpin, J. Krogstie, S. Nurcan, H. A. Proper, R. Schmidt, R. Ukor (Eds.), Enterprise, Business-Process and Information Systems Modeling – 11th International Workshop, BPMDS 2010, and 15th International Conference, EMMSAD 2010, held at CAiSE 2010, Hammamet, Tunisia, June 7-8, 2010. Proceedings, volume 50 of *Lecture Notes in Business Information Processing*, Springer, Heidelberg, Germany, Tunis, Tunesia, 2010, pp. 182–194. doi:10.1007/978-3-642-13051-9_16.

[45] V. Maquil, O. Zephir, E. Ras, Creating Metaphors for Tangible User Interfaces in Collaborative Urban Planning: Questions for Designers and Developers, in: Proceedings of COOP 2012, May 30 – June 1, Marseille, France, 2012.

[46] E. Ras, V. Maquil, M. Foulonneau, T. Latour, Using tangible user interfaces for technology-based assessment – Advantages and challenges, in: CAA 2012 International Conference, July 10-11, University of Southampton, UK, 2012.