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RESEARCH NOTES

From Expert Discipline to Common Practice: A Vision and Research Agenda for Extending the Reach of Enterprise Modeling

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Abstract The benefits of enterprise modeling (EM) and its contribution to organizational tasks are largely undisputed in business and information systems engineering. EM as a discipline has been around for several decades but is typically performed by a limited number of people in organizations with an affinity to modeling. What is captured in models is only a fragment of what ought to be captured. Thus, this research note argues that EM is far from its maximum potential. Many people develop some kind of model in their local practice without thinking about it consciously. Exploiting the potential of this "grass roots modeling" could lead to groundbreaking innovations. The aim is to investigate integration of the established practices of modeling with local practices of creating and using model-like artifacts of relevance for the overall organization. The paper develops a vision for extending the reach of EM, identifies research areas contributing to the vision and proposes elements of a future research agenda.

Keywords Enterprise modeling · Grass roots modeling · Research agenda

1 Introduction

Enterprise modeling (EM) as a discipline in academic research and as a practice in organizations has been around

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for several decades. The body of knowledge represented by academic publications is huge and includes conceptual, technical and practice-oriented topics (cf. Sect. 2). The benefits of EM and its contribution to organizational tasks, such as business model development, enterprise transformation or IT/business alignment, are largely undisputed. New challenges are addressed by research work (Zdravkovic et al. 2015) and will eventually be taken up by industrial practice. This view of EM as mature discipline might be somewhat idealistic, but is shared by many in the discipline (Frank et al. 2014). However, for initiating serious innovation the internal perspective of the EM community is not helpful because it fails to address hindrances to large-scale adoption of modeling in practice. Many organizational actors refuse to create and maintain enterprise models, find modeling cumbersome, or do not utilize models.

In this research note, the authors use an external perspective to discuss the state of the art of EM and propose a research agenda to overcome the above mentioned adoption challenge. We argue that EM is a long way from reaching its maximum potential, has yet to prove its benefits for the majority of business stakeholders, and has not succeeded in being regarded mission-critical in most enterprises (cf. Sect. 3). EM is typically used by only few actors in the organization with an affinity to methods and modeling (cf. Sect. 2). What is captured in enterprise models is only a fragment of what could be captured. Many people actually develop some model instance without realizing that they are modeling (Hoppenbrouwers and Rouwette 2012). Examples are spreadsheets used to capture features of products, presentation slides that comprise architectural designs, sketches in drawing tools that specify information flows, or even structured collections of facts. The content of such documents often is highly valuable, but difficult to retrieve (Hermans 2012), and not managed in coherence with dependent content. It is content which often meets all characteristics of a model (e.g., abstraction, reduction for a purpose at hand, pragmatic use), but is obstructed by a specific document format. Exploiting the potential of this wide-spread "grass roots modeling" and using the unexplored contents in existing, non-model documents and conversations could lead to groundbreaking innovations and increased impact of EM in practice.

This challenge identified for enterprise modeling has some similarities to challenges in software development and product innovation where collective intelligence and user innovation were applied successfully to open the disciplines for wider user communities. Thus, EM should try to take advantage or inspiration from developments in the wider area of business information systems. At the same time, a successful implementation of grass-roots modeling and modeling for masses could lead to new insights which should be investigated regarding their potential to provide feedback for innovation and user-driven software development.

Starting from a brief state of the art in EM (Sect. 2), we elaborate on "modeling for the masses" by describing the problem (Sect. 3), specifying the vision (Sect. 4), discussing the state of practice in areas contributing to the vision (Sect. 5), identifying the dimensions of the challenge, and finally proposing topics for future work (Sect. 6).

From a methodical perspective, the elicitation of the vision and roadmap started with a collection and discussion of issues and challenges in the field of EM which had similarities to a focus group. 25 researchers in EM and related fields met in a 5-day Dagstuhl seminar to discuss organizational agility and flexibility in moderated sessions. In the next step, a smaller group of 8 researchers used lightweight knowledge elicitation techniques (e.g., brainstorming, concept sorting, topic map) to develop the initial version of a vision basically consisting of important topics and related goals. Each topic was assigned to members of the group for further investigation. After the seminar, several iterations of individual work of the group members on the topics (e.g., literature analysis to systematically identify research areas contributing to the vision) combined with collaborative work (integrating the individual findings into the vision and research agenda) followed. In the following, the resulting paper was subject to two peer-review cycles which both led to improved versions.

2 Enterprise Modeling: A Brief State of the Art

This state-of-the-art summary can only touch on published research work in EM and illustrate the broad spectrum of existing work.

EM addresses the systematic analysis and modeling of processes, organization and product structures, IT-systems and any other perspective relevant for the modeling purpose (Vernadat 1996). EM is a research discipline with a long tradition and a large body of knowledge. A detailed account of EM approaches is provided in (Sandkuhl et al. 2014).

The scientific literature identifies several central aspects of EM (see, e.g., Sandkuhl et al. 2014; Henderson-Sellers et al. 2014; Frank 2014a), such as the *modeling procedure* or *method*, the *model* that results from modeling, the *tool support,* and the *organizational structures* that frame modeling. However, not all scholars agree: some consider constructional and functional structures as part of modeling methods and argue that they cannot be separated (Dietz 2006); others emphasize the importance of meta-models and modeling languages for capturing different perspectives (Frank 2014b). Tool support is often considered inseparable from modeling approaches and notations (ISO/IEC 24744 2014), but is sometimes reduced to a modeling aid (Sandkuhl et al. 2014).

In addition, participative modeling and involving different stakeholder groups in EM also has a long tradition (e.g., Stirna et al. 2007), and domain-specific modeling languages (DSML) (Van Deursen et al. 2000) attempt to offer EM that targets specific stakeholder groups. Other research areas include meta-modeling and language development (Fill and Karagiannis 2013), method engineering (Henderson-Sellers et al. 2014), reference modeling (Martens et al. 2015), approaches and tools for analysis and transformation of models (Kusel et al. 2015), frameworks for evaluating and improving the quality of models (Krogstie 2016), and approaches for investigating the value of EM (Benkenstein et al. 2016). Areas like enterprise architecture management (Winter 2014), service engineering (Fischbach et al. 2013) and capability management (Berzisa et al. 2015) also use, extend and specialize EM knowledge.

3 The Problem

Starting from the hypothesis that EM has a lot of unexploited potential which requires a wider integration of local practices, this section explores causes for the current "problem" in EM from the perspectives of driving stakeholder concerns and sustained model utilization. Stakeholder groups that have a holistic, long-term perspective, e.g., corporate IT, believe that architecture is no emergent feature of a complex system, but needs to be explicitly planned, implemented, monitored and adjusted (Winter 2004). Their concerns require models to cover multiple aspects, all relevant artifacts, complete artifact life cycles, and to be coherent. The EM discipline matured over the last decades by (Winter 2014):

1. diversifying its modeling object from IT infrastructure, software and data over IT applications, business processes, functions/capabilities, organizational roles and products to value creation or business models,
2. widening its modeling scope from single solutions over functional/business areas to enterprise-wide or cross-enterprise models,
3. extending its scope from a single object layer to the complete business-to-IT stack, and
4. representing not only as-is or to-be states, but also roadmaps to cover the entire life cycle of modeled objects and to support evolution.

In contrast to the aforementioned enterprise-wide concerns of certain stakeholder groups, most other stakeholder groups in organizations have more focused or short-term interests. They prefer an opportunistic systems development process with an emergent architecture. Their concerns require models that cover selected aspects, comprise only artifacts that are locally relevant, focus on current design problem, and do not have to be fully coherent with other focus models. As a result, a plethora of 'local' models (Theunissen and van Heesch 2016) can be found that are used by only one stakeholder group for 'local' analysis and design, or that serve as boundary objects (Star and Griesemer 1989) between two stakeholder groups. The co-existence of different concerns in organizations leads to a co-existence of enterprise and local models at various levels of scope, rigor, and (potential) impact that are not necessarily coherent.

As the benefits of EM were increasingly appreciated by large organizations, the EM discipline matured, and various 'architect' role models were established. A recent study revealed that "more mature architectures do not necessarily lead to business value" (Ross and Quaadgras 2012, p. 1). In contrast to the historical value perception and impact increase of EM, a turning point might have been reached where additional EM effort is not justified by appropriate impact gains any more (Winter 2014).

The authors of the mentioned study believe that the capped impact results from the fact that EM is driven primarily by architects and is valued primarily by IT people, so that its effects are often limited to these groups. EM thus appears to be an elitist discipline. It may be possible to reach other stakeholder groups with EM, e.g., by implementing tight governance mechanisms that enforce local model coherence. However, such measures would not only require a high governance effort, but they would also not gain acceptance with the "90% of an organization" (Gardner et al. 2012) that have primarily local, focused concerns.

A straightforward remedy would be lightweight EM approaches that do not focus on traditional EM qualities like completeness and coherence, but on usefulness and impact. Such approaches would need to support not only architects and corporate IT, but also organizational stakeholders that might benefit from improved models supporting their local analysis, design and/or decision problems.

Another aspect of the "problem" results from the fact that models are used for many purposes. In (Krogstie 2016), the following usage areas are mentioned among others: model mapping, human sense-making, model deployment and activation, systems development, model implementation and standardization. Many applications of modeling are limited to one usage area, and thus provide limited value. The long-term added-value of modeling can only be realized when models are used over a longer time and across different areas (Krogstie et al. 2013). To enable this potential, a broader and long-term usage has to be considered right from the start and needs to be systematically pursued across the organization (Krogstie et al. 2013). With models originally designed for sense-making in a limited group of actors, one will often experience limitations that originate from the modeling approaches and tools originally deployed (Krogstie et al. 2006). Few actors retain ownership over these models over a long time span so that models gradually decay.

Both aspects of the "problem" in EM point into a similar direction: The traditional understanding of enterprise models as an instrument of architects and certain roles in project teams must be extended to include additional stakeholder groups that have decentral concerns, thereby providing a broader organizational embedding of enterprise models – which in turn helps to create sufficient added-value to justify the EM invest.

4 The Vision

Organizations need to share knowledge. A precondition for knowledge sharing are artifacts and practices that support representing and transferring knowledge across time and space. Whereas in most areas of human conduct, one-dimensional (textual) languages, either informal (natural language) or formal (as in mathematics) have traditionally been used for this purpose, we observe a growing importance of two and multi-dimensional representational forms, such as EM. To extend the impact of EM, we propose technologies and approaches that overcome the elitist character of EM and enable 'normal' knowledge workers to be active modelers, both by adapting the applications they are using to support their daily work and by providing support for specific non-routine situations.

Our vision for EM in an organizational context is as follows:

> Ten years from now, the majority of organizational stakeholders uses enterprise modeling (often without noticing it) to capture, store, distribute, integrate and retrieve essential knowledge relevant for their local practices in a way that supports long-term, cross-concern organizational objectives.

This vision includes many aspects that need further elaboration:

- Modeling is embedded in everyday work: Non-experts in modeling do modeling, sometimes even without knowing it;
- Different kinds of model content, formats and purposes can be extracted, integrated and federated on demand, either through human intervention or driven by a symbiosis of humans and intelligent agents;
- Local practices in capturing knowledge can be specific yet integrative with other local practices;
- Modeling by non-experts (a.k.a. grass-roots modeling) and professional modeling co-exist in synergetic use. Models are not primarily developed for one specific purpose, but can be more flexibly used for several purposes;
- Completeness, coherence and rigor requirements to models are softened towards possibilities for incomplete, partly formalized and contradictory model components. Modeling quality and alignment between models that may be partially incoherent is not enforced by tight governance mechanisms, but subject to local decision-making. Enterprise-wide concerns are implemented by influencing local stakeholders.

Modeling is not an end, i.e. a purpose on its own, but a means to an end. Exemplary EM ends are business model/business process innovation, communication support and sense-making, IT/business alignment, or local decision-making problems of any kind.

5 Research Areas Contributing to the Vision

For attaining the vision outlined in Sect. 4, approaches, methods and technologies from various areas in computer science, business information systems and social sciences will have to be involved, of which some already exist but many others still have to be adapted or even newly developed. This section identifies and summarizes such related areas. The dimensions used to identify relevant research were stakeholder and user involvement, collaboration and co-creation, technology innovations and their effects, and – models being an artifact – the lifecycle of IT-artifacts. These dimensions already materialized during the initial part of the research, i.e., the 5-day seminar (see Sect. 1). They were later refined into dimensions of the research agenda (see Sect. 6).

5.1 Practice Theory

Organizational research (Corradi et al. 2010; Schatzki 2001) and workplace studies (Luff et al. 2000) have taken a "practice turn" in recent years. Studying practices leads to an understanding of what human actors really do, how they make sense of what they do, and how they communicate this knowledge to others. This perspective appealed to researchers of Computer Supported Cooperative Work who wanted to understand frequent failures and unexpected obstacles when adopting collaborative technologies in the field (see e.g., Luff and Heath 1998). Typically, workplace studies have a focus on how artifacts (traditional or digital) are embedded in human activities, e.g., as a tool, as material, as knowledge repository, or as symbol. We see a great potential in applying the tool set of practice theory to enterprise modeling. The study of EM practices enhances our understanding what both modeling laymen and experts really do when they model, what the role of modeling artifacts really is, how several actors collaborate in modeling or using models, how EM practices blend into other work practices, and how structures like power and information flows are shaped by EM practices.

Based on the practice theory viewpoint, researchers reject applying inflexible models which do not meet the information demand of stakeholders or heavy-weight tools to manage architectural information (Roth et al. 2013; Matthes et al. 2013). They rather propose to use lightweight *collaboration tools* to support enterprise modeling activities. For example, the Hybrid Wiki (Matthes et al. 2013) empowers information carriers and enterprise architects to collaboratively and incrementally develop and manage a model in a bottom-up fashion, blending unstructured content (e.g., free text) with structure (types, attributes, and relationships) (Reschenhofer et al. 2016). This corresponds to approaches for evolutionary information systems where users are empowered to modify existing systems for their personal use in order to incrementally meet changing business requirements at run-time (Neumann et al. 2014).

5.2 Participation, User-Centered Innovation and Collective Intelligence

Participatory modeling investigates how multi-touch tabletops and mobile devices or data-glasses can be applied in EM to enhance user participation, what differences in group productivity, role distribution or model acceptance exist compared to conventional modeling and what adaptations in notations and tools should be made (see, e.g., Gutschmidt et al. 2017; Kolb et al. 2013). If participatory modeling addresses innovations, it overlaps with the area of user-centered innovations (Brenner et al. 2015; von Hippel 2005). It thus needs to be investigated, how EM methods and languages need to be designed to maximize the benefit of user involvement. Small scale user participation can focus on 'lead user' (von Hippel 2005). Lead users have a special interest and competence in the domain; they are able to quickly identify showstoppers and suggest improvements at an early stage. By large scale user participation, the benefits of collective intelligence (CI) can be reaped. CI integrates existing knowledge from various perspectives and thus lead to collective knowledge systems where humans and machines interact seamlessly (Leimeister 2010; Gruber 2008). CI offers a theoretical lens for studying grassroots modeling as a combination and recombination of simpler building blocks, called genes, in which actors (who), encouraged by incentives (why), work toward goals (what) in specific ways (how) (Leimeister 2010). Further research should also draw on crowdsourcing (Blohm et al. 2013) as a supplementary lens on grassroots modeling, in order to investigate how to: assess user-generated models; disseminate them to the appropriate organizational actors; and assimilate them into existing work practices to generate value for the organization. From this perspective, to leverage grassroots modeling, an organization must develop its model absorption capability by: designing appropriate modeling platforms; filtering large volumes of highly varied grass-roots models; attracting a critical mass of contributors; integrating the platforms and contributors within the organization; and encouraging information exchange (Blohm et al. 2013).

5.3 Assistive Technologies

Assistive technologies for model development and model improvement aim at improving or complementing computer-based EM tools. They include the use of functionality from recommendation systems to support modelers in finding suitable constructs or modeling elements (Fellmann et al. 2015), the use of semantic technologies to interpret the meaning of labels and detect similar constructs in other models (Fill 2011) or to investigate model patterns or model fragments (Delfmann et al. 2010) which could be reused to make models more detailed or precise, or to extend them. In doing so assistive technologies can also make modeling more accessible to broader user communities.

Visual Languages aim to enhance a better understanding of all stakeholders. The focus here is the interaction of humans and machines through visual representations on computer screens (Narayanan and Hübscher 1998). Although the technical realization of visual languages in the context of EM is today often accomplished using meta modeling platforms such as Eclipse-EMF, or ADOxx, the theories and innovative approaches developed in visual language research are very valuable. Examples include the technique of visual semantic zooming recently proposed by Yoon and Myers for better understanding and interacting with changes in program code (Yoon and Myers 2015) or approaches for recording, processing, and visualizing changes in diagrams (Maier and Minas 2015). Semantic annotations (Fill 2016) can be a means of assistance and distinct development languages (Fill et al. 2012) ease the development of domain-specific modeling tools.

5.4 Gamification

Through gamification, researchers strive to improve not only model understanding, but most of all making models and modeling easier, more accessible for stakeholders, more 'usable' (Oppl 2016), and even more engaging. Here, modeling activities are framed as games (Hoppenbrouwers and Rouwette 2012). 'Dialogue games' consist of conversational moves in which modelers propose, discuss, accept or reject model elements, while rapidly switching the specific focus of the dialogue in a goal-driven fashion (Hoppenbrouwers and Rouwette 2012). Collaborative 'modeling games' can assist modelers with respect to guidance and facilitation (partly or fully automated) and the structured registering of discussion and decisions concerning a model (Fellmann et al. 2015; Hoppenbrouwers and Stokkum 2013).

5.5 Knowledge Management

Knowledge engineering (Studer et al. 1998) and enterprise knowledge modeling (Lillehagen and Krogstie 2009) contribute to systematic development and reuse of knowledge by offering methods, tools and approaches for capturing knowledge in defined representations in order to support the entire lifecycle of organizational knowledge management (Dalkir 2013). Knowledge management from an organizational perspective addresses how to establish systematic knowledge management in an organization in terms of activities and organizational structures required (e.g., Probst et al. 2000; Nonaka 1994). Already in her seminal case study "Learning from Notes", Orlikowski (1993) shows that successful knowledge management depends on appropriate incentive mechanisms for sharing knowledge. In many situations, the success of an employee depends on his knowledge and sharing may endanger his career. Recently, knowledge management has moved away from "heavy-weight" conscious structured data capture to "light weight" approaches relying on enterprise social media and knowledge farming from company structured and unstructured data (records, documents, communication traces). Thus knowledge management calls EM for new, lighter approaches to capture and document knowledge.

5.6 Semantic Web

The concept of a "semantic web originated from the vision that machines are enabled to conduct automated reasoning and can thus infer information from resources on the world-wide-web (Berners-Lee et al. 2001). In contrast to semi-formal approaches in the area of conceptual modeling that primarily build on a formal syntax with semantics expressed in natural language (Fraser et al. 1994), approaches based on semantic web technologies typically strive for logic-based models that enable automated processing (Obrst 2003). The spectrum of using semantic web technologies in EM stretches from the use of distinct ontology languages for describing enterprise models to the transformation of enterprise models to formal ontologies, e.g., (Thomas and Fellmann 2007), up to the lightweight approaches of using semantic annotations for processing enterprise model content, e.g., Fill 2011). New standards and vocabularies for open data exchange mean that open semantic data may in the future increasingly overlap with EM. For example, open semantic data sets can be used both for enriching and mining enterprise models, and enterprise models can be used to help users by making sense of, providing context for and offering access to semantically annotated information. The research challenge is to connect the implicit, but often tacit, semantic assumptions made in enterprise models and EM languages (Anaya et al. 2010) to link them to the bottom-up web of semantically annotated data where anyone can contribute anything about any topic using their preferred vocabulary (Allemang and Hendler 2011). Research on these aspects has to combine approaches from traditional conceptual enterprise modeling with techniques found in artificial intelligence, semantic web, and linked dinfluence on the actor's response towardsata.

5.7 Architectural Thinking

Architectural Thinking (AT) (Winter 2014; Ross and Quaadgras 2012) offers a perspective on how to widen stakeholder involvement in organizations. AT is understood as *the way of thinking and acting throughout an organization*, i.e. not restricted to architects and system developers, *that considers holistic, long-term system aspects as well as fundamental system design and evolution principles in day-to-day decision making* (e.g., change requests). A traditional approach to implement AT is to 'bring architecture to the business', i.e. to build up modeling competences and responsibilities in business lines (and not in a central architecture unit), thereby enabling additional people in the organization to 'architecturally think and act'. As many organizations however failed to motivate business lines to 'architecturally think and act', research has been addressing the creation of enabling conditions for AT. Weiss et al. (2013) adopted institutional theory as a lens to analyze the obvious reluctance of many organizational actors to comply with enterprise-wide norms and guidelines. They show that social legitimacy, efficiency, organizational grounding and trust have significant influence on the actor's response towards "restriction of design freedom" (Dietz 2008) and propose that supportive conditions need to be created in the form that

- actors gain social fitness inside the organization when complying with architectural guidelines (social legitimacy),
- actors become more efficient when following guidelines (efficiency),
- architecture management is anchored within the organization's values in terms of strategy definition, top management support or the position in the organizational hierarchy (organizational grounding), and
- actors are confident that the architecture does the right things right (trust).

6 Elements of a Future Research Agenda

Future research in the field will have to tackle various challenges related to our vision, which have to address seven dimensions:

- Stakeholder dimension: who creates and uses models? Several stakeholder categories have to be distinguished: grass-roots (i.e., everybody without any particular modeling competence), participative (domain and modeling experts in a joint effort), expert (modeling experts create/use models), and computer (machine-generated or interpreted models). A better understanding is required about how models or model-like content is created and used by non-traditional users.
- Concern dimension: what importance do models have for which stakeholder concerns? Which types of concerns of which stakeholder groups can typically be supported by which types of models and which types of content?
- Model understandability dimension: how easily understood is a model by different stakeholders? Some representations are relatively easy to understand for certain stakeholders (e.g., visual models), others difficult (e.g., ontology representations), and many levels exist inbetween these extremes. The formality of a representation is often related to its understandability.
- Model scope dimension: which scope is the model relevant for? Categories could be that a model is relevant for individuals only, for an organization unit, for the enterprise as a whole, or for an ecosystem.
- Model processing dimension: What tasks have to be supported across model representations, scopes, purposes and local practices? Examples are alignment, visualization, ambiguity detection, approximation (find similar models), annotating, and integration. What extent of ambiguity can be accepted?
- Value and quality dimension: which factors affect quality, success, failure, utility of modeling?
- Model lifecycle dimension: what phases of model lifecycles are to be distinguished? Are they different for different kinds of models?

The topics in a research agenda have to address above dimensions for all aspects of our vision. This leads to a two-dimensional research agenda (see Table 1), i.e., the dimensions are put into relation to the vision's aspects identified in Sect. 4. The areas discussed in Sect. 5 were analyzed for relevant topics and positioned in Table 1. The topics are presented in the following sections, each section addressing a different aspect. All topics show significant demand for more research. In case early work in the field exists, this has been summarized in Sect. 5.

6.1 Modeling is Embedded in Everyday Work

One of the central elements of the vision is that modeling has to be embedded in everyday work; people do modeling without noticing it.

From a *stakeholder perspective*, more work is needed on how grass-roots model creation and use can be supported and stimulated. Modeling methods need to be examined in view of what can be performed without traditional modeling tools. More knowledge is required on how to increase the social legitimacy of models, i.e., to make light-weight model creation acceptable and normal in a community and not only among lead users.

Presentation and representation of models has to investigate how everyday work happens and what can be adequate for situations of model creation and use. Potential areas of research are how light-weight conceptual modeling can immerse into work environments, adaptations to actual work contexts of model users and merging, work environment and subject of work in model-generated work environments.

The scope of models must be managed to ensure that the right content is represented in the right way for each actor. Research is needed on how to automatically derive and maintain model views tailored to particular purposes and how to integrate and federate locally created models into global ones.

Future research in the *model concern dimension* has to address whether the concerns typically supported by modeling methods are exhaustive and sufficient. Models are known to capture "as-is" or "to-be" situations, transitions between these situations, strategic, tactical or operational purposes, etc. When modeling is embedded in everyday work, thinking in such categories might not be adequate.

When it comes to *the processing of models*, there is hardly any integration between modeling tools and information systems, office and groupware products. Only a few

Table 1 Research topics relevant for attaining the vision

Dimension vision's aspect	Stakeholders	Model representation	Model scope	Concern/purpose	Processing	Value and quality	Lifecycle
1. Modeling is embedded in everyday work	Under-standing grass roots model use and creation, improve social legitimacy	Model-generated workspace, model visualization	Model views, simplification of EM methods	Interactive model support	Integrate modeling tools and platforms in enterprise environments	Comprehension of 'just sufficient' models	Model at run-time, from ad-hoc model to elaborated model
2. Model combination, integration, federation on demand	Semantic enrichment when maturing models	Semantic aspects of model representation	Going from local to global scope	Model integration, support of reuse situations	Understanding model semantics by intelligent agents	Manual and automatic quality assurance of models	Model federation and integration lifecycle, value of models
3. Specific but integrative local practices	Light-weight practices for local workers. simplification of EM tool	Local representations, semantic annotations, DSML	Local practice, models as boundary objects	Sense-making and local communication	Visualization, semantic integration of models + documents	Model comprehension and stake-holder agreement	Projects and work tasks, knowledge services for EM
4. Grass-roots and professional modeling in synergy	Practices for expert modelers and local workers	Transition between light- and heavy-weight modeling approach	Organizational practice	Alignment of local practices	Semantic enrichment, model merging	Model availability using agreed syntax	Organizational memory
5. Softened requirements to completeness, rigor	Local workers, modeling games	Local representations, multiple stakeholder environments	Local practice, hybrid models/ methods/tools	Sense-making and local comm., limited degree of enterprise wide integration	Process unstructured model content, e.g., NLP, document and EM mining	Model comprehension and stakeholder agreement	Short-term projects and local work tasks

exceptions attempt such integration, e.g., active knowledge modeling. More research is required for embedding modeling-like functionality in tools which traditionally are not related to modeling. This integration should be explored for model creation and use, as well as for linking, combining and integrating model content with the content of enterprise systems.

Regarding the *quality of models* we need to understand which of the established quality criteria too strongly constrain grass-roots modeling and which ones are so important that they need to be observed. Many other characteristics of model quality, like semantic or pragmatic quality, need better understanding of how a certain application domain or community of modelers influence these characteristics.

A *lifecycle view* on models is used in the tool selection or method discussion. The lifecycle view probably needs to be changed into several lifecycles. When modeling is embedded in everyday work, a model might come into existence earlier than in conventional expert modeling. A collection of notes taken for defining business rules might be considered first stages of modeling even though they do not include any formal elements. Stakeholders may also consider models finished much earlier, i.e., at the end of the lifecycle, when expert modelers would still require more refinements.

6.2 Model Combination, Integration, Federation on Demand

Grass-roots modeling will tend to produce, change and use model views that are detached from global enterprise models. Combining, integrating and federating local models on demand therefore becomes a research area, as well as re-integrating them into global enterprise models.

Research on semantic enrichment can potentially inform on-demand integration or federation of local models. For example, natural-language analysis techniques can be used to extract semantics from labels in local models, offering evidence of semantic connections between elements in different models. This task resembles problems in text analysis and semantic clustering. Seamlessly integrating local models and embedding them within global ones can benefit from advances in machine learning, but gold standards to bootstrap supervised learning approaches are yet missing.

Research is also needed to explore how standard identifiers [e.g., personal ids, product ids, or IRIs used in linked open data (Bizer et al. 2009)] can be used to define unambiguously which elements in which models should be merged or tightly connected because they represent the same thing, event or concept. The modeling languages themselves are also a source of semantics that can be leveraged for model integration and federation. This task becomes easier if the semantics of global enterprise models are well defined. Research is needed on how existing work for semantically describing models and modeling languages (Opdahl et al. 2012) can be extended to interoperate grass-roots along with professional models.

Research on usage context can also be used to identify and better support local modeling practices. Research should investigate whether and how similarities in modeling contexts can help identify models that should be managed in similar ways, or that are candidates for integration or federation.

More research effort is needed on how user-created local models embedded within global ones can encourage workers to balance attention between a local, task-oriented and a global, strategic focus.

6.3 Specific but Integrative Local Practices

The technical environments used for EM today are rather complex. This hinders capturing knowledge from users who are not familiar with underlying concepts. Existing local practices for capturing knowledge thus need to be integrated with EM approaches. Research is required on lightweight EM practices that do not require extensive familiarity with underlying formalisms. A recent example can be found in quality management where the analysis of local practices led to an EM method for business process improvement (Fill and Johannsen 2016). Future EM tools should rely on interaction and interface paradigms that represent the standard in office environments, e.g., browser-based applications today and in the future deviceless interaction. The locally-adapted model representation formats and languages could be enriched for enabling machine-based analyses (Bork and Fill 2014). This can either be accomplished through traditional adaptations of a modeling language or through semantic annotations. Through local practices, the scope of enterprise models has to be widened to act as boundary objects between domain experts and machine-processing mechanisms. Besides the establishment of interfaces to complimentary disciplines such as big data analysis (Fill and Johannsen 2016), future research should also open up new domains for EM – e.g., for conceptualizing modeling methods for the legal/compliance domain or for cyber-physical systems. The processing of model information needs to be accomplished via new approaches for visualizing model contents (Iyer and Basole 2016) and the semantic integration of models. Recent notable examples include an approach for conceptual modeling to manage the complexity in Smart City planning (Bork et al. 2015). These practices are used for projects and work tasks as well as in the context of knowledge services for enterprise modeling, i.e., to integrate local modeling practices.

6.4 Grass-Roots Modeling and Professional Modeling in Synergy

In addition to the existing methods for participative EM, other *stakeholder-centric* approaches are needed for creating synergy between expert modeling and grass-roots modeling. One aspect is how to create an organizational culture and mutual acceptance of diverse stakeholder groups as well as ways to exchange modeling results, develop joint practices, and establish a heterogeneous community of modelers. It is important to identify lead users and liaise with them in this process. Another aspect is the development of methods that allow for dynamic role distributions.

Although some experience exists how to migrate from light-weight to stricter or heavy-weight *model representations*, much more research is required. The representation of light-weight models usually only has less type and entity or relationship categories than conventional modeling languages. Future work could include type migration strategies, loose type coupling or informal mappings from light-weight to conventional representations.

The *scope of modeling* to a large extent depends on an organization's practice in the use of expert modeling. Grass-root modeling can extend the established organizational scope. Research needs to investigate strategies for extending it efficiently and systematically.

We need to better understand how modeling concerns of local practices and communities differ from concerns of expert modelers, and which concerns are suitable for exploring the use of grass-root modeling.

Tool-related research should investigate how to automatically extract local view models from model-like content, ensure that they remain synchronized over time, and present them in ways that are well-suited for local users. Research should investigate approaches to suggest opportunities for reuse of knowledge captured in local views across organizations. Some tasks could be performed quietly by autonomous agents that maintain the model, leading to a new type of smart model.

Both *value and quality of models* and modeling will have to more clearly integrate the perspective of grass-roots modelers. Non-expert modelers so far have been primarily considered as users of models. When grass-root modeling focusses more on model creation and models as carrier of knowledge, other value and quality aspects need to be investigated. Grass-root modelers and experts do not necessarily have to agree on joint criteria, but the perception of quality should not be mutually accepted. A synergetic view on expert and grass-root modeling would benefit from a joint view on the *lifecycle of models* which could serve as a guideline to how to organize modeling.

6.5 Softened Requirements to Completeness, Coherence and Rigor

Moving from traditional modeling approaches to a more generic set of representations, the number of stakeholders and their need for traditional model quality varies increasingly. Moving from an informal representation to a more formal one often means improving the model quality in a way found beneficial within the organization. How to motivate people for such shifts is a research issue.

In general, the combined set of knowledge carriers will take different forms, but not all knowledge should be represented as a formal model. The right balance of representational forms is an important research topic.

In particular when supporting local practice, one would expect informal representations to be of most importance. If one can instill at least the use of semi-formal notations for certain types of knowledge (e.g., simple process models), this improves the potential distribution of knowledge and supports reorganization and migration of workers internally. Again, the question of the right balance is an interesting research topic. One could argue that all new knowledge is created among individuals and local communities, only some of it needs to mature for organizational-wide use and relevance. Research is needed to investigate when this maturing process of enterprise knowledge, including some formalization, is beneficial.

The social quality of models in the sense of agreement is perhaps not as important when assumptions can be readily tested or used among a limited number of people. How to soften the requirement to model quality but still keep the models appropriate needs to be investigated.

The formality of the approach will differ considerably depending on if the modeling aims at supporting local sense-making or maintaining organizational memory. Again, research on the need and useful mechanisms for knowledge maturing and model reuse is important.

7 Summary and Future Work

Motivated by current challenges in EM, we have proposed a new vision for the field: *"from expert discipline to common practice"*, aiming to better exploit the potential of EM in future enterprises. We have identified mid-term and long-term research challenges towards this vision and pieced them into a research agenda. Future work will both have to address the challenges themselves through new research efforts and to continuously revise and extend the agenda in light of the results. An important precondition is to discuss the vision and its consequences thoroughly in the enterprise modeling community.

Many of the issues and concerns we have raised are related to *people*: how they use models, what concerns they have, with whom they need to communicate, etc. Eliciting (model engineering) requirements alone may not provide sufficiently broad and deep understanding, unless it is augmented with behavioral and social perspectives that provide insights on motivations, perceptions, concerns, emergence, etc. This calls not necessarily for a methodological evolution of the EM discipline, but for a better integration with other (IS) research communities. With broader foundations, new innovative approaches to mass user-oriented modeling, human-model interaction and the processing of information contained in models can be developed and shared across communities.

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