Towards Design Thinking Knowledge Graphs

Anca Moldovan[1], Robert Andrei Buchmann[2,*]

[1]Babeş-Bolyai University, Teodor Mihali 58-60, Cluj-Napoca 400591, Romania

Abstract

The Design Thinking (DT) practice encompasses a tacit Knowledge Management framework and a participatory ideation workshop format. As a structured workshop, its phases produce artifacts that facilitate case-specific knowledge capture and ideation refinement – from empathized pains and gains to prototyped behavior, typically intended to be implemented in products, services or work procedures. DT practitioners follow a pragmatic mission of workshop facilitation to enforce decision-making and idea commitment among the present stakeholders. There is, however, a gap in terms of a Knowledge Management strategy, as practitioners follow a manual approach of handling volatile DT artifacts - sticky notes, voting dots, sketches that are used and dismissed once conclusions are reached. Audio-video documentation may serve for archiving, but not for granular semantic distinctions and retrospective traceability; on-line tools provide graphic digital boards, but their focus is on participatory experience and communication, not on knowledge representation.

This work proposes that model-driven Knowledge Graphs can act as a knowledge externalization tool - to capture the conceptual framework underlying Design Thinking workshop and content management, thus potentially bridging the gap between DT workshop deployment and its cognitive framework function. A tacit conceptualization can be detected when inspecting the DT stages and taxonomy of artifacts - we hereby propose a Knowledge Graph design to externalize this conceptualization, while also mimicking the visual appearance and user experience of digital boards with the help of a DSML (domain-specific modeling language). Together they are intended to fulfil both the visualization and knowledge structuring functions of DT-based innovation boards.

Keywords

Design Thinking, knowledge graphs, participatory ideation, idea scoring, DSML,

1. Introduction

Design Thinking (DT) [1] is a collaboration practice executed through semi-structured workshops that follow specific phases and produce artifacts typically documented with the help of physical items – e.g. sticky notes, cardboard figurines. These items are manipulated across "innovation boards" - workspaces that provide some notion of content grouping, color-coded distinctions, and refinement stages. More recently and partly motivated by the pandemic, digital collaboration tools enabled online participation in such workshops, replacing physical artifacts with digital items that must be dragged and dropped across digital boards and virtual containers. Such online tools are mostly participatory usability facilitators, supporting the accumulation and layout of graphical elements, leveraging visual cues and content grouping that mimic the physical innovation boards. However, they lack machine-readable semantic distinctions and an integrative conceptual model encompassing all items, in terms of the tacit knowledge of the DT facilitators - acquired through personal training and experience.

At the other end of the knowledge acquisition spectrum, Knowledge Graphs (KG) [2] are a means of structuring and representing knowledge assets in semantic networks of associations governed by a conceptual model (vocabulary or ontology) that is shared within a domain of knowledge or practice. They are sufficiently formal to be processed by machines through querying and deductive reasoning, lately also advocated in tandem with generative AI, in various Graph RAG integration patterns [3], or as a representation format for model-based Digital Twins [4]. Digital Twins of the Design Thinking experience have been proposed in [5] with the aim of capturing haptic storyboarding content from physical DT environments. That proposal shares with our project the idea of employing domain-specific

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*Corresponding author.

anca.moldovan@econ.ubbcluj.ro (A. Moldovan); robert.buchmann@econ.ubbcluj.ro (R. A. Buchmann)

0009-0005-7273-1325 (A. Moldovan); 0000-0002-7385-1610 (R. A. Buchmann)

modeling languages (DSMLs) for knowledge capture – in their case, to provide a visual canvas for figurine-based scenario building. However, the focus there is not on capturing the DT domain-specificity, but the specificity of the application area; moreover, it does not have in scope a KG treatment.

Domain-specific diagrammatic modeling shares with the DT digital boards the bi-dimensional canvas and the dragging-dropping usage experience, but also adds through meta-models a governing knowledge structure to enable traceability and semantic annotation. These can be leveraged by Knowledge Management Systems, underlying a potential Knowledge Management capability that could augment the DT practice. While using a DSML can mimic the content accumulation experience on a diagrammatic canvas, Knowledge Graphs can preserve semantic distinctions and relations of those content items. This tandem enables retrospective analysis and semantic traceability over a repository of DT content across different sessions, projects, or gravitating around a solution-seeking (product development) effort.

Therefore, the nature of this research fits the Design Science paradigm [6] due to the artifact-oriented nature and the prescriptive solution sought by the research questions. These are formulated below in accordance with the taxonomy of the DSR questions from [7]:

RQ1 *How can we represent the knowledge a DT facilitator applies during a DT workshop and associated content management, to enable retrospective Knowledge Management capabilities?*

RQ2 *How can we build and operationalize means for capturing such knowledge representations, while mimicking the traditional digital board innovation experience of on-line DT tools?*

For the first question, we designed a Knowledge Graph that incorporates items collected on digital DT boards, distinguished by their practice-specific semantics, workshop phases and dependencies (i.e. who contributed what). To answer the second question, we resort to model-driven engineering and build a DSML that partly mimics the visual user experience of dropping items on color-coded digital DT boards to produce the KG design proposed for the first question.

The work was initially introduced as a doctoral consortium vision paper in [8], later extended in a workshop paper that introduced a BPMN extension for Design Thinking [9] - i.e. focusing on the procedural aspects of managing a DT event. The new version presented in this paper shifts focus towards the KG treatment and a DSML that has less of a procedural nature, aiming to capture the semantic network of associations between content objects and their contributors, to populate a KG design proposal tailored to concrete competency questions.

The remainder of the paper is structured as follows: Section 2 will advocate the convergence of DT and Knowledge Management Systems with the help of KGs and will formulate the proposal as a Design Science problem. Section 3 will motivate the problem based on authors' own experience as a DT facilitator. Section 4 will formulate the design proposition for the KG and the DSML, illustrated through some SPARQL queries as proxy for competency questions. The paper will continue with comments on related works pointing to an on-going preoccupation for conceptualizing the ideation and solution-seeking activities. Conclusions and outlook on future work will wrap up the paper.

2. Design Thinking and Knowledge Management Systems: A Proposed Convergence

Knowledge Graphs [2] have been developed for many domains or specialized for enterprise-specific systems, but there is still a lack of contributions employing them in the conceptualization of the Design Thinking framework. Although DT is essentially a cognitive framework [10] concerned with co-evolving problem/solution spaces [11], it is pragmatically trained and deployed as a templated workshopping practice [12]. During execution, DT workshops rely on the tacit knowledge of facilitators transferred through socialization, on the problem domain knowledge of participants and on template-supported manipulation of content objects (depicting ideas, preferences or other aspects pertaining to the problem/solution spaces). This collaborative experience has commonalities with enterprise modeling practices such as participatory modeling [13] or "modeling conferencing" sessions [14], but it lacks both an explicit metamodel to govern the knowledge capture activities and the semantics-driven tooling to allow the knowledge to be leveraged in Knowledge Management Systems; our work intends

to fill this gap on both method and tooling level.

Balancing semi-procedural execution and creative content emergence, a DT workshop is both a stepwise process of a semi-structured kind (hence our attempt to apply a BPMN modeling lens in [9]) and a collaboration-driven network of contributions that are refined and accumulated through staged interactions between stakeholders, under facilitator guidance. The manipulation of DT content objects on "innovation boards" enhances presentation and communication through color/shape/containment distinctions, but fails to ensure machine-readable semantic traceability – which would be a core requirement in any Knowledge Management System. The desideratum of augmenting Innovation Management with Knowledge Management [15] can leverage the semantic network of content objects acquired over a series of DT workshops or sessions, enabling a range of knowledge work cases - retrospective analysis, ideation analytics and Idea Scoring, machine reasoning over a corpus of semantically-distinguishable content items in relation to solution-seeking projects and their stakeholder participation.

In terms of Nonaka's knowledge conversion cycle [16], DT relies heavily on socialization. Once an individual workshop's objectives are achieved, knowledge of how those objectives were achieved remains volatile, at best documented in audio-video recordings for archiving purposes, but lacking any semantic traceability or granularly engineered context. This shortcoming is especially noticeable when the need for Idea Scoring arises, when many alternative ideas from multiple DT sessions must be ranked and documented in a catalog that can serve prioritization, budgeting, and general traceability e.g. what exactly was the motivation of an idea, what alternative idea paths worth revisiting have been raised.

Considering this gap, our design-oriented research (not only in terms of the DT application domain, but also as a Design Science effort) proposes that such a Knowledge Management capability should be built on a conceptualization of the DT workshopping and content management experience. We introduce a treatment where Knowledge Graphs and DSMLs are employed in tandem to enable both granular knowledge capture and storage as semantic networks. The work is motivated by extensive empirical experience of the first author with more than 80 DT workshops where the shortcoming of not having available a Knowledge Management capability manifested downstream along Innovation Management processes, constraining their flexibility and impact. Recognizing this, we reflect on the ontological structures that govern the DT workshop and cognitive framework, the taxonomy of artifacts/content items that DT produces, and the granular semantic associations emerging between them.

3. Problem Identification

3.1. Problem Context and Background

Developed and popularized by the design consultancy IDEO [17], the DT approach has gained traction beyond the design domain, becoming a key methodology in business schools and corporate Research-Development departments to drive innovation by managing ideation pathways.

DT follows (and iterates through) a sequence of stages, each employing a variety of heterogeneous tools contributing to a fragmented experience (37 tools and methods identified in [18]). DT workshops produce specific artifacts and outcomes contributed by a multi-disciplinary team – ideas, idea refinements or depictions (e.g. storyboards), preference statements (e.g. votes and prioritization cues). An alternation of Divergence and Convergence activities is typically imposed in most workshop stages – Divergence for stimulating heterogeneous creative contributions and Convergence for clustering, prioritization and commitment through voting and filtering techniques.

One widely adopted DT macro-process follows five phases:

1. Empathize – This phase focuses on understanding needs, based on methods such as interviews, stories, focus groups to identify perceptions and perspectives and their subjective importance to the target stakeholders. The templated toolset typically includes the Persona user profiling and associated Empathy Maps. This supports the collection of demographic context attributes and associations to Pains, Gains or other empathy aspects – e.g. what stakeholders represented by a Persona are expected to see, hear, do and generally experience.

2. Define – This phase focuses on scoping the problem and framing the problem statement around insights derived from the empathizing stage, considering the weighted importance for the targeted audience. HMW questions (How might we...?) or user stories typically support granular decompositions of problem statements at this stage.

3. Ideate – This phase generates diverse potential solutions, through approaches like brainstorming and mind mapping. Divergence of ideas is alternated with convergence by clustering and voting to achieve commitment to a short list of solution proposals to be considered for prototyping.

4. Prototype – This phase creates tangible or mock-up representations of selected ideas to provide impressions that can collect feedback, and to refine them accordingly. Visual representations can include storyboards linked to process diagrams (e.g. the Scene2Model approach [19]) to depict the behavior, the user interaction or the customer journey to be provided by an envisioned solution.

5. Test – This phase focuses on evaluating "prototypes" with users, gathering feedback and iterating for refinements. This implies sizing the effort to turn solution propositions into reality, scoring alternative ideas, and possibly revisiting alternative ideation pathways for future workshops or iterations – here the need for analysis and traceability addressed by our work explicitly comes to surface and extends into the post-workshop reflection and retrospectives.

In the context of innovation decision-making, Idea Scoring is a class of analytical methods for evaluating and prioritizing ideas based on specific criteria [20] - factors such as feasibility, desirability, cost-effectiveness, potential impact. Idea analytics relates to the emergent ideation performed during DT workshops and to broader innovation management in general. The scoring and traceability of ideas can benefit from the engineering of an innovation context (who, what, where, when) [21]. Our work presumes that this context can be enriched by the ideation process where the ideas are gleaned from, i.e. the originating DT workshop of any solution idea and the content items being produced and refined there – persona-based rationale, pain points that motivated an idea, stakeholders who expressed preference for it, process diagram that represents it. This aspect reclaims a Knowledge Management capability to maintain an explicitly engineered ideation context. Context engineering has been a long-term concern in enterprise modeling [22] and we believe it can be transferred to the problem-solution mappings of DT, a practice that actually resides in the semantic space of enterprise systems and was often tackled from an enterprise modeling perspective [19, 23].

3.2. Experience-based Insights

This research was informed by two decades of the first author's experience in business consulting, particularly in the area of product and service development across ITC, telecommunications, fast moving goods, and NGOs. During this time a recurring challenge has become evident - the lack of conceptual clarity and granularity regarding the different stages that constitute the creative solution development, the dependencies, content flows and taxonomies of artifacts involved in DT. Some central questions that arise in business innovation strategies are: *How does an organization select the most appropriate innovation for investment? How does it fall back to alternatives and how can it look back to the semantic context that generated innovative ideas?* The principles of innovation investment decision-making remain remarkably similar across sectors and enterprise types - funding allocation and execution hinge not only on the strength of the business case, but also on the organization's ability to prioritize innovation and manage the knowledge generated around it.

Organizations are often confronted with competing financial imperatives - the dilemma typically revolves around whether to allocate resources toward cutting-edge technological advancements, enhancing operational agility, improving customer experience, or other strategic financial investments. In such trade-offs, the empathized aspects (Pains/Gains), the HMW questions become traceable properties that characterize and distinguish different innovation ideas. However, despite the existing semi-structured idea co-creation processes, Innovation Knowledge Management and evaluation faces a gap between the environment where the innovation was fostered (Design Thinking) and where it is evaluated for implementation. The consequences of this are redundant iterations of similar ideas, unstructured and untraceable feedback mechanisms, loss of context, ultimately leading to inefficient resource allocation.

Over the past years, a series of more than 80 DT workshops involving the first author across diverse domains — including customer journey mapping, communication strategy development, and organizational restructuring — has provided occasions for observing this gap, and for reflecting on the meta-concepts involved in the DT experience as innovation enabler.

Figure 1 shows some exemplary artifacts manipulated during physical DT workshop deployments – post-its, cardboard figures, voting dots, grouping devices, color-coding and labeling – are spread across "innovation boards" and workspaces. Digital DT tooling also focuses on mimicking a similar experience. In our work, we propose a DSML-based approach was chosen because diagrammatic modeling can also mimic that user experience of dragging, dropping, grouping and annotation visual items, but also adds to the experience machine-readable distinctions governed by a domain-specific rigorous conceptualization. In our case the domain is the DT practice itself and a conceptualization of it is iteratively refined into a model and a Knowledge Graph schema to represent this practice.

Figure 1: Exemplary objects from a Design Thinking physical setting (author's own archive)

The ability to catalogue, score and semantically characterize ideas remains an underdeveloped aspect of contemporary Innovation Management. Our proposal can enable semantically richer, contextualized idea capture - by integrating DT principles with Knowledge Management Systems as defined in [24], organizations can navigate the complexity of ideation practices and their problem-solution mapping efforts. Contributing to that, Idea Scoring can bring metadata and evaluation criteria to be aggregated while navigating the captured knowledge - in Table 1 we show a simplified example of an idea's evaluative annotations drawn from series of past DT workshops; such criteria can accompany and guide the idea refinement effort, or can inform retrospective reporting on past annotated ideas.

Table 1
Exemplary Idea Scoring annotations selected from authors's DT projects.

	Evaluation criteria	Description	Score (0 to 3)	Evaluator
1	Competitive advantage	How big is the differentiation against other competitors in the market?		
2	Probable future economic benefits	How much is the amount of business volume we can expect from this outcome and why? (for one year)		
3	Project Roadmap (intention to complete)	Estimated duration and effort		
4	Resources adequate and available to complete and use or sell the asset	Availability of development capabilities		
5	Ability to sell	Sales potential		
6	Technical Feasibility	Technical readiness maturity in first year		
7	Expenditures can be reliably measured	Measurability		

4. Model-driven Knowledge Graphs for Design Thinking

4.1. Knowledge Graph Competence and Design Decisions

As we intend to develop a modeling method that streamlines a DSML and a KG schema to capture DT-specific knowledge while mimicking the visual content management of digital innovation boards, the best methodological fit is the framework of Design Science Research (DSR) [25]. Therefore, the design problem is formulated according in DSR terms: we aim to close the gap between Knowledge Management and Design Thinking practices *(the problem context)*, by introducing a knowledge capture approach based on KGs and a DSML *(the proposed artifact)*, in order to operationalize the tacit conceptualization of DT experience *(the characteristics of the artifact)* to satisfy the need for retrospective analysis, Idea Scoring and aggregated reporting over a number of past DT experiences *(the stakeholder goals)*.

As an initial source of design decisions, we looked at constructs available on innovation board templates (such as those in Figure 1) employed during the first author's DT practice and traced their direct dependencies: *Persona* boards help establish familiarity with a fictive profile (including demographic data and concerns) of those impacted by the problem. *Empathy Maps* further structure the Persona concerns and classify them across empathy aspects: what the persona stakeholders would see, hear, think, what they would say and do in contexts where the problem manifests; empathy aspects end up summarized as Pains and Gains. The *How Might We* boards collect questions that reformulate the Pains and Gains into inquisitive phrasing to reveal more granular facets and problem sub-scopes that must be prioritized before advancing to the discussion of actual solutions. *Divergence and Convergence* boards collect solution propositions; in the Divergence phase, creativity and extrapolation are encouraged to foster diversity of participant viewpoints; in the Convergence phase a collaborative qualitative filtering reduces multitudes to candidates for subsequent prototyping. Idea annotation and scoring as suggested by Table 1 can be involved to support certain ideas. The *Prototyping* boards collect representations of actionable solutions for the candidate ideas; they can take the form of interface mock-ups, storyboards, or even process diagrams for enhanced procedural rigor of the scenarios, as proposed in experimental DT tooling such as Scene2Model[1] [19], but also in the convergence of business process-customer journey modeling advocated in commercial tools[26].

While template-based tools are valuable to stimulate user experience, their integration under a common ontology remains underexplored and is the primary preoccupation of our research. Figure 2 shows how these constructs are semantically integrated into an RDF Knowledge Graph designed in the early DSR iteration of this work. These are gleaned from the tacit knowledge of the DT practitioner, but are not machine-readable semantic constructs available in their toolsets – a critical requirement for Knowledge Management Systems. A KG treatment also opens the potential of aligning with BPMN descriptions of the DT solutions, with diagrams incorporated as named graphs by resorting to BPMN-to-RDF conversion approaches experimentally available in both literature [27] and educational tooling such (see Bee-Up[2]). To illustrate this, a miniature BPMN diagram is explicitly linked at the bottom of Figure 2. Another asset that can be "semantically docked" in this structure are Idea Scoring annotations – as metadata or comments collected during the DT workshop during filtering and convergence activities. The application case illustrated here is (a real case) initiative to devise solutions for providing safe digital experiences to children without affecting their digital skills. The solution selected for the example is that of a gamified app that also educates children through quizzes, to allow them to recognize cyberthreats while integrating the gamification approach with family routines. The knowledge structure is grouped under a named graph representing a DT session further annotated with the project and enterprise where the DT experience was deployed.

Navigation of stakeholder involvement in ideation activities: Which ideas were voted on by a particular stakeholder (e.g. John) and in which DT workshop session?

```
SELECT ?workshopSession ?idea
```

[1] https://scene2model.omilab.org/
[2] https://bee-up.omilab.org/activities/bee-up/

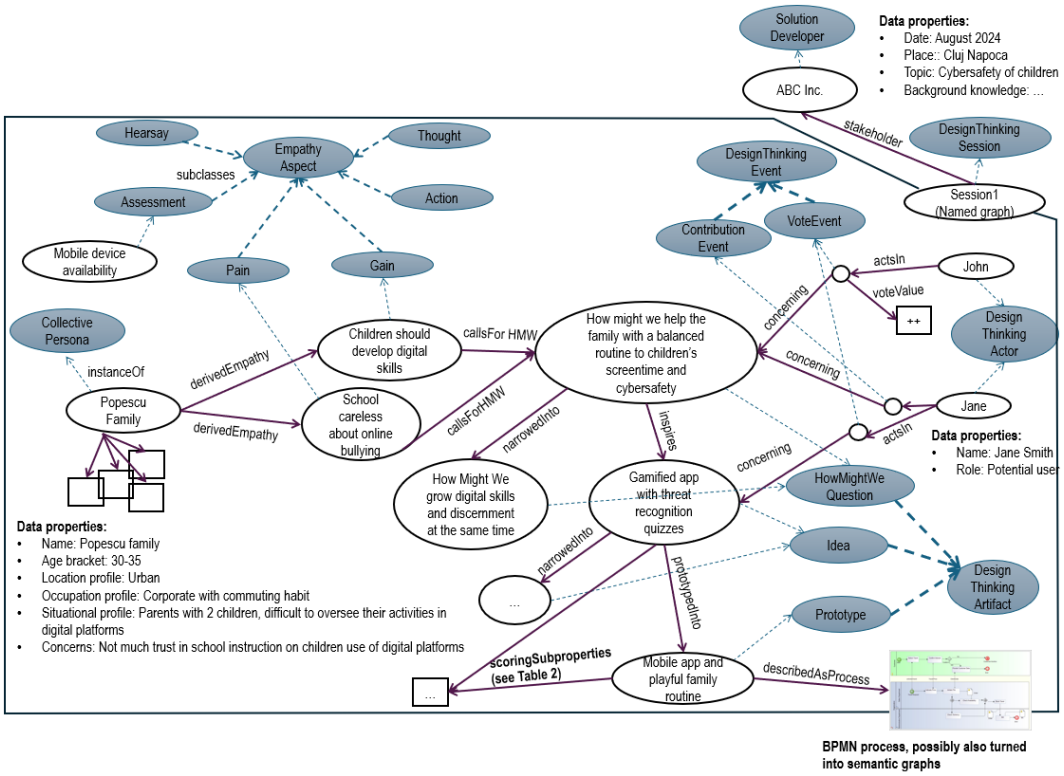

Figure 2: Exemplary KG design gleaned from DT innovation boards constructs [8]

```
WHERE {
GRAPH ?workshopSession{:John :actsIn [a :VoteEvent; :concerning ?idea]}
}
```

Navigation of alternatives: Which are the alternate ideas (and their refined versions) tackling a specific Pain point (e.g. :SchoolIsCareless), alternatives to a selected one (e.g. :GamifiedApp) in case it hits a feasibility obstacle?

```
SELECT ?idea
WHERE
{
:SchoolIsCareless a :Pain; :callsForHMW/:inspires/:narrowedInto* ?idea
FILTER (?idea != :GamifiedApp)
}
```

Tracing solution elements from their original motivation: What BPMN tasks are to be executed to enact the ideas tackling a particular Pain point (e.g. SchoolIsCareless) of a particular Persona?

```
SELECT ?task
WHERE
{
:SchoolIsCareless a :Pain;
:callsForHMW/:inspires/:prototypedInto/:describedAsProcess ?g.
GRAPH :metamodel {?g a :BPMNModel}
GRAPH ?g {?task a :BPMNTask}
}
```

Tracing back outcomes to their original motivation: What is the persona (and its attributes) whose Pain or Gain points inspired a specific idea (e.g. :GamifiedApp), and in which DT session did we commit to that?

```
SELECT ?session ?persona ?prop ?value
WHERE
{
GRAPH ?session
{?persona a :Persona; :derivedEmpathy ?e; ?prop ?value. ?prop a owl:DataProperty.
?e a ?empathyAspect; :callsForHMW/:inspires :GamifiedApp.
FILTER (?empathyAspect IN (:Pain, :Gain))}
}
```

4.2. Model-based Enabler for Capturing Design Thinking Knowledge Graphs

One major challenge in KG management is how to build them without resorting to technical expertise with KG standards like RDF. As contributors to the OMiLAB ecosystem [4], we traditionally use diagrammatic tools built on the ADOxx meta-modeling platform – which also offers a plug-in for producing RDF named graphs out of domain-specific diagrams. The plug-in was introduced in [28], and is adaptable, possibly with some SPARQL CONSTRUCT transformations, to any DSML implemented in ADOxx. Figure 3 shows an exemplary diagrammatic design comprising several interlinked diagram types, capable of producing the KG structure presented in Figure 2. At the same time, it tries to mimic the digital board experience – of gradual linking, grouping of items and collecting voting dots by dropping them into visual containers/boards. A workshop management view is provided as a high-level summary of workshop sessions, with the participants and their involvement in DT-specific activities such as voting/ideation sessions. Links across the diagrams ensure the semantic integration needed to produce the knowledge structure (hyperlinks between the diagrams also become RDF graph edges).

The metamodel governing this diagrammatic design is shown in Figure 4, partitioned in three new model types of the propose DSML, and a BPMN legacy model type – i.e. the BPMN implementation

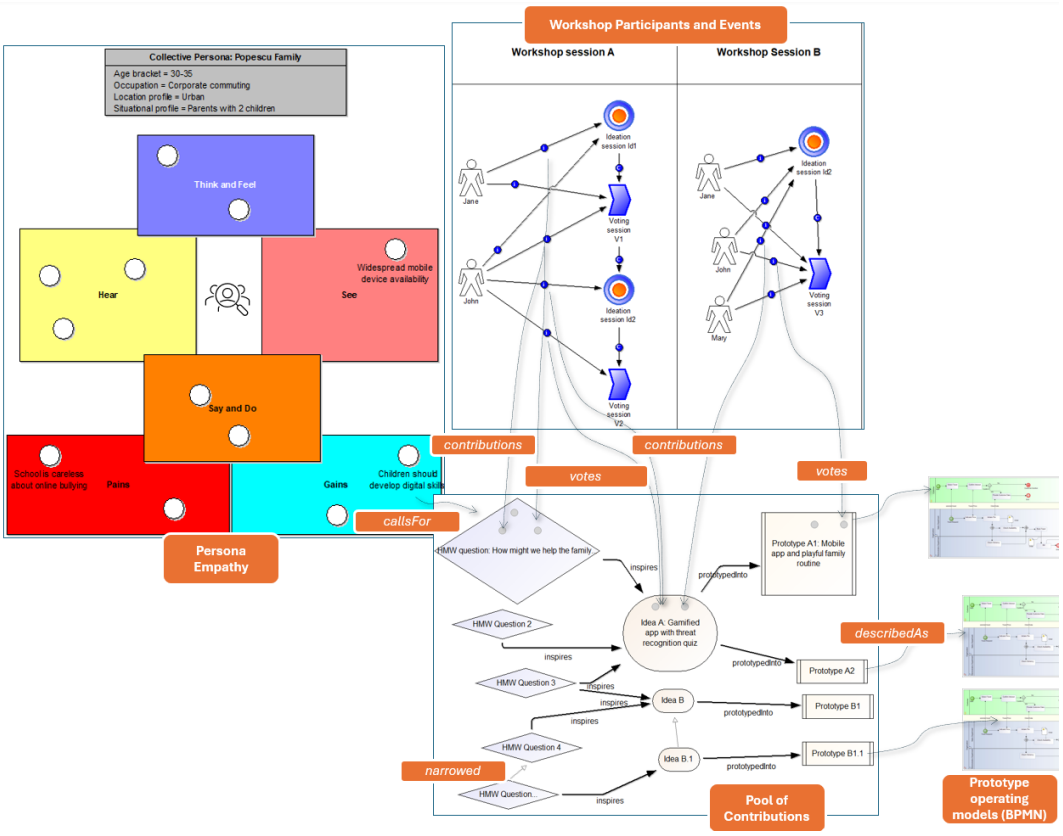

Figure 3: Visual diagramming experience based on a DSML to produce the DT Knowledge Graphs

already available for ADOxx through the educational modeling tool Bee-Up[3]. The legacy BPMN conceptualization is not detailed here, showing only its "semantic docking point" (see the model type labelled as *Pool of contributions*. This inventory of artifacts provides visual connections between content objects (e.g. which question inspired which idea towards which prototype) and refinement relationships ("narrowedInto") to preserve gradually refined versions of artifacts. The grey dots visible in the *Pool of contributions* enable the linking of the other model types:

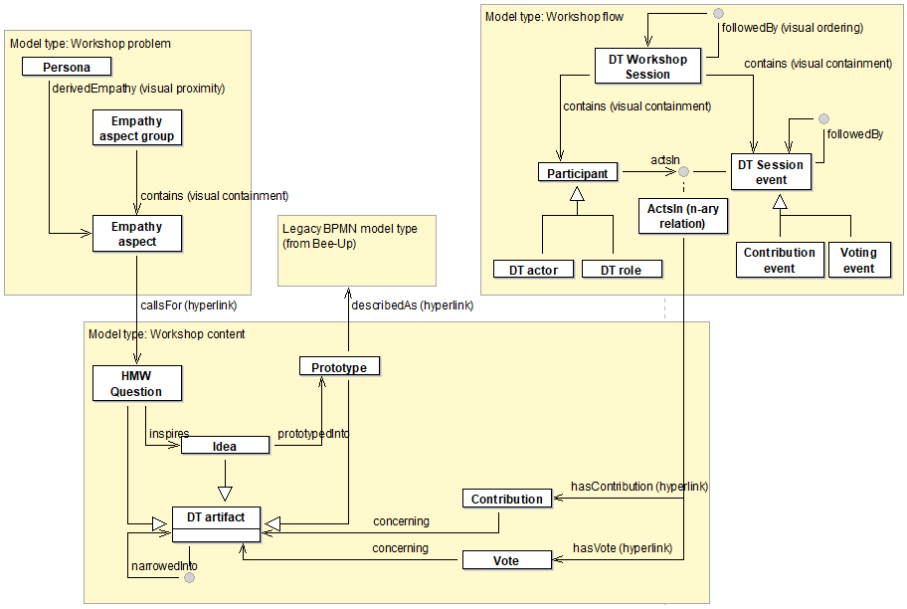

Figure 4: DSML Metamodel as a conceptualization bridge between the diagram in Fig. 3 and the KG in Fig. 2

1. From the *Workshop problem* model type ("Persona-Empathy" in Figure 3) the empathy aspects (Pains, Gains and the sensory categories) can be linked as the motivation and inspiration to pose the HowMightWe questions. The Empathy Map is accompanied by a single Persona with its own data properties - a non-explicit relationship links the Persona and the Empathy Map by their simple presence in the same diagram (i.e. the visual proximity relation suggested by the metamodel, as the diagram acts as an aggregator of its contents and this is further transferred to the RDF graphs). The digital board experience of dropping elements in containers and color-coding can be noticed in Fig. 4, with containment determining connectivity and typing of dropped elements into the Knowledge Graph.

2. From the *Workshop flow* model type (labelled as "Participant and Events" in Figure 3) the involvement of stakeholders (roles or instances) in the sequenced subsessions/events of each DT workshop phase is annotated by an n-ary relationships – first visually connecting the participant to the subsession, then hyperlinking this visual connection to the item that represents contribution or voting to/for specific content objects artifacts present in the *Workshop content* model type.

Several limitations are notable in the current version: Visually, as noticeable also in Figure 3, it fully relies on repurposed symbols from the legacy Bee-Up modeling tool - i.e. with changed semantics indicated by the metamodel. Future DSR iterations will be invested in tailoring a visual identity in line with Moody's principles for visual syntax [29]. The project currently focuses on language competency supported by semantic queries and traceability; we also leave collaborative usability out of scope, as we focus on the conceptual unpacking effort.

5. Related Work

There is an extensive body of knowledge concerning the design-oriented preoccupation with collaborative innovation methodologies [30], and their intersection with knowledge-driven innovation. For a long

[3]https://bee-up.omilab.org/activities/bee-up/

time, DT practitioners have been proposing templated tools, even pointing to the need of an-notation and scoring [31] however without resorting to a model-driven KG treatment. The KG approach has been suggested at the Knowledge Management-Innovation Management intersection [32] [33], although what is missing there is the pragmatic focus on the DT practice and experience.

Effective problem-solution thinking is crucial for business-IT alignment, yet communication and methodological gaps persist, requiring design-oriented contributions. Problem-solution chains [34] are a recent proposition that is minimalist and not explicitly anchored in the DT experience. Participatory enterprise modeling [35] has many aspects in common with the DT collaborative approach, the main difference residing in the degree of formal refinement of concepts and the specificity of artifacts that participants need to manipulate. Empirical investigations in how participatory enterprise modeling can be organized reveal semantics and taxonomies that can be mapped to a process-centric collaborative conceptualization approach [13]. Tangible business process modeling makes further steps towards the physical collaboration setup employed by DT, aiming to make BPMN more accessible to non-experts [36]. Our own previous work focused on a DSML that brings BPMN closer to DT processes and content flows, by relaxing its imperative style of modeling [9] – comparatively, in this paper the DSML is designed more for alignment with a KG design, focusing on content objects and content flows rather than workflows. Research on DSML-DT convergence shows an interest in the conceptual unpacking of the DT experience [19]: in Scene2Model tool reported there, physical storyboards are digitized and associated with BPMN treatment designs. The tooling was effectively implemented across various research and industrial initiatives, as a key component of the OMiLAB Digital Ecosystem [4] which also relies on the ADOxx meta-modeling environment similar to our work. Unlike the DSML hereby proposed, Scene2Model does not aim to capture the DT cognitive framework and content roll-out, only the "solution storyboards" through visual figurines. Our proposal also continues prior work on visualization of Design Thinking assets with the help of DSMLs [23] [37] however such prior works were only interested in visualization with diagrams as an end in themselves, not as mediators towards populating DT Knowledge Graphs.

6. Conclusions and Future Work

The paper makes a design proposition for a DSML and a Knowledge Graph to structure the tacit knowledge driving DT facilitation, considering the artifacts and contributions involved during a DT workshop. Based on extensive experience of the authors with DT workshops, in both physical deployments and digital innovation board usage, a conceptual unpacking effort took place under the DSR framework – aiming to enable a Knowledge Management perspective on the DT experience. Future work aims to (a) first integrate this proposition with our earlier, process-centric and BPMN-based DSML [9], in order to balance a workflow view and a content flow view; (b) secondly, we have to align the KG design with the resulting multi-perspective DSML; (c) finally, we need to design a visual notation for the resulting language instead of repurposing existing symbols (from the Bee-Up modeling tool). Afterwards, the DSR evaluation phase will advance in line with the VVE evaluation framework introduced in [38] – this will also involve looking at Knowledge Management use cases picked from industry partners to inform iterative refinements of the proposed conceptualization.

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Declaration on Generative AI

The author(s) have not employed any Generative AI tools.

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