Towards a process-centric knowledge management capability for design thinking

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Abstract

This early-stage Design Science project aims to develop a Knowledge Management treatment for the practice of Design Thinking (DT). The knowledge generated by a DT workshop manifests on two levels: knowledge pertaining to how the collaborative efforts of the workshop unfold and knowledge pertaining to the workshop outcomes (the developed solutions). To enable bidirectional traceability between the two levels, the Knowledge Management capability we envision must be able to capture both and to semantically relate them - by mapping out workshop phases, participant contributions and accumulated content artifacts that emerge during DT activities, from early-stage empathizing to late-stage prototyping.

DT facilitators, regardless of whether they use a physical setting or on-line digital boards, manipulate content objects that are useful for ad-hoc group communication but lack the semantic and granular traceability needed to turn them into meaningfully connected knowledge objects – that can be accumulated over a history of DT workshops or consultancy projects, to enable a Knowledge Management capability for DT practice. Workshop facilitators rely strongly on tacit knowledge accumulated through their own training and application experience; occasionally, archival documentation may be gathered, but lacks the conceptual structuring needed to answer retrospective questions – e.g. who contributed which idea, motivated by what, and what ideas were dropped behind, in which phase of which workshop session. This gap requires both method and tool support, therefore we hereby report on an initial Design Science iteration to fill this gap.

The proposed method builds on the procedural knowledge that can be captured by means of business process modeling; therefore, we apply BPMN on DT contexts wherever know-how can be chronologically described. However, since DT is a less structured practice than the typical workflows handled in Business Process Management, we must extend BPMN on metamodeling level in order to reconcile it with a conceptualization of the DT practice, the specificity of DT tasks, resources, artifacts, events etc. The result is a DSML (domain-specific modeling language) that combines the procedural nature of BPMN with the collaborative ideation perspective of Design Thinking. This implies that the envisioned Knowledge Management capability will rely on a process-centric conceptualization core to enable retrospective analysis of DT work, aggregated reporting, knowledge transfer and analytics over a history of documented DT efforts. To make the proposed treatment actionable, it is implemented on the ADOxx metamodeling platform by extending the open BPMN implementation available in the OMILAB modeling ecosystem.

Keywords

collaborative ideation, innovation knowledge management, design thinking, BPMN extension

1. Introduction

For many years now, Business Process Model and Notation (BPMN) [1] has been the primary standard for business process modeling. Despite wide adoption, when it comes to representing human-centric problem solving and solution ideation, BPMN falls short in expressing the adequate specificity and concerns. Coming from a different direction that values creativity and idea co-creation, Design Thinking (DT) [2] evolved from design and engineering disciplines to guide ideation activities, while accounting for user emotions and motivation captured during dedicated workshopping activities that are managed by trained DT facilitators. Our work aims to achieve a

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reconciliation between the two, which we believe can act as an enabler of a Knowledge Management capability over past or planned DT activities and outcomes.

Since the paradigm of Knowledge Management Systems [3] has recognized for a long time the support that conceptual modeling (especially business process modeling) can provide - as means of knowledge capture, retrieval and transfer – we opt for our method to be based on a process-centric DSML (domain-specific modeling language) that repurposes BPMN for the practical domain of DT. This also builds on our OMILAB community [4] involvement and past successful projects on supporting enterprise knowledge management with DSMLs [5]. The experience is also the basis for the choice of technology, as we opted to implement a Design Science demonstrator on the ADOxx metamodeling platform[2], prominently used in the DSML engineering eco-system of the OMILAB community (see several projects catalogued in [6]).

The post-pandemic business landscape has accelerated the pace of innovation, emphasizing the importance of cross-functional solution development collaborations among geographically and culturally diverse teams. This shift underscores the growing need for human-centric approaches that prioritize informal ideation and empathy in innovation idea generation. Design Thinking (DT) plays a crucial role in fostering human-centric solutions by emphasizing empathy, iterative problem-solving, and interdisciplinary collaboration. As a complexity management approach [7], DT enables organizations to navigate complexity by alternating diversification of ideas (*divergence*) with selection and filtering (*convergence*) towards idea commitment and gradually refined idea prototyping. DT provides a semi-structured and flexible framework that helps businesses understand user needs, ideate creative solutions, prototype rapidly, and refine processes based on real-world feedback.

However, the facilitation of a DT workshop and DT-based consultancies rely on the knowledge DT practitioners, and this knowledge is most often tacit or at best documented in unstructured ways that do not allow granular traceability - of what happened during a consultancy history of such workshops, across related sessions, or what is planned for future instances of such events.

Even if it is a semi-structured practice, there exist guidelines, chronologies of activities and expected events in how DT is or should be deployed. Although DT workshops rarely mention the terms "business process" and "workflow", procedural knowledge manifests both tacitly and explicitly on at least two levels that we have identified during our experience as workshop facilitators over the years:

Level 1 (DT as a process). The entire deployment of a DT workshop is a sequence of phases, each including activities of specific types. While the high-level phases are well-known and fixed, frequently the order of internal activities is at the discretion of the workshop facilitator, or it can be event-driven - depending on whether the facilitator identifies divagations or commitments, depending on the DT workshop timeframe and prioritization. The literature reports some attempts at formulating the DT process as a multi-stage BPMN process, but this is done mostly as a reference model [8], and not as a flexible modeling method - to describe either To-Be planning of future workshops, or As-Is roll-out of historical DT workshops.

Level 2 (DT solutions as processes). The recent literature also shows a preoccupation in modeling problem-solution flows [9]. The nature of the solutions being developed during a DT workshop vary with the nature of the problem and the sector where the problem must be tackled. This determines also the nature of "prototypes" realized through DT – they can be tactile/physical, software (mockups or even functional proofs-of-concept) but also more abstract in nature. Abstract prototypes are prescriptive ways of doing things and of reacting to events ("recipes", work procedures). In numerous cases, prototypes can be (and end up being) mapped on some form of flowcharts by a business analyst: a process illustrated in a storyboard, a software usage process, a customer journey process of interacting with a service or a physical product. In other words, outcomes of DT workshops are often semi-structured business processes even though most

[2] https://adoxx.org/

participants would never mention processes. The preferred wording in DT communication is more layperson-oriented:

- “problems”, "pains" (typically a frustrating process or a feared event within a process);
- “solutions”, "gains" (typically an improved process, an event avoided by preventive or corrective actions added to an existing process);
- “idea” (typically a process variant or process path);
- "prototype" (an illustration or simulation of a process).

This tacit presence of processes, either as control flows or content flows, motivated us to apply a process management perspective to both DT knowledge levels (i.e. *DT as process* and *DT solution as process*). As a starting point we picked BPMN due to its wide adoption, despite the general impression that, being the preferred standard for imperative, fully ordered and structured process, it would not be adequate for the free collaboration flow of a DT workshop. Since we aim for a balance between imperative control flow and flexible content management, we consider this a conceptualization gap to be addressed in this project at metamodeling level - as it will be detailed in Sections 2 and 4. This means that we need to add, on top of BPMN, the domain-specificity of how DT is conceptualized by a facilitator and workshop participants.

Thus, our efforts lead to the development of a BPMN-based DSML (domain-specific modeling language) implemented on the ADOxx metamodeling platform[3]. For this, we extend the open BPMN implementation available in the Bee-Up modeling tool. Bee-Up[4] is a multi-language modeling toolkit (for BPMN, UML, Petri Nets, DMN, EPC, ER) shared among members of the OMILAB community of practice; it was described in [10] a key component of the OMILAB Digital Innovation environment as it is commonly used as a core for DSMLs that are built around one of its supported fundamental languages.

2. Problem context and problem statement

Design Science Research (DSR) research investigates artifacts in context to improve situations and practices observed in that context, in relation to some stakeholder goals and possibly generalizable to a global practice beyond the observed context [11,12]. The locally observed practice is our direct hands-on experience with Design Thinking based on more than 80 workshops managed by the first author as a certified DT facilitator; another stream of experience is the project-based application of the OMILAB Digital Innovation environment [10] that contains a storyboarding tool for DT named Scene2Model[5] [13].

In recent workshops organized specifically to kick-off this research, we have applied a meta-knowledge observation strategy on the actions and events that are detectable during the delivery of a DT innovation workshop. Besides analyzing the think-aloud delivery and guidelines of the facilitator, we aimed to identify taxonomies of content elements that accumulate on the collaboration boards and the tacit/implicit relationships that connect those elements in terms of content flow and influence. The observations informed a conceptualization to be described in this paper, reflecting the domain-specific semantics that are the basis of the hereby proposed DSML (BPMN extension).

Design Thinking is typically deployed as a semi-structured workshop following well-defined phases, where each phase includes some flexibly ordered activities to be orchestrated by the facilitator. The activities generate a diversity of artifacts depending on the focus of each specific phase. Oftentimes, these artifacts are accumulated only on presentation boards – as physical post-its and voting dots or, since the pandemic crisis prioritized on-line collaboration, visual shapes moved across digital boards in browser-based interfaces and apps. Even in the on-line digital boards (such

[3] https://adoxx.org/
[4] https://bee-up.omilab.org/activities/bee-up/
[5] https://scene2model.omilab.org/

as Miro[6]), the focus remains on ad-hoc communication and on the front-end experience of collaboration - navigating content by zooming and panning, dragging and dropping color-coded visual items or item groupings. Such elements may persist in digital tooling for future revisiting, but they lack a rigorous, machine-readable conceptual structure with explicit semantics to allow for their subsequent traceability and querying, to enable a reporting capability over a history of such workshop sessions.

On the other hand, such capabilities are commonly available in Business Process Management tooling, often based on process querying methods [14] over conceptual workflow patterns, and we aim to repurpose such approaches for DT knowledge management – either over past DT experience, or to inform future DT planning and knowledge transfer. This may introduce new roles in DT practice (e.g. a DT knowledge/complexity manager) or can extend the toolkits of the DT facilitator with new analytical enablers. Use cases vary with the competency questions that a repository of such "DT processes" are relevant to be satisfied, through model queries navigating the relations between content elements and workshopping activities – examples will be highlighted in Section 5.

The integration of DT content management tools and conceptual modeling platforms must enable a structured transition from user-centered ideation to knowledge accumulation and ultimately innovation analysis. Tools such as empathy maps, personas, and journey mapping support the exploration of stakeholder needs, while platforms like Miro facilitate collaborative ideation, but DT resources are typically spread between distinct tools and content silos lacking inter-connectivity outside some navigational hyperlinking to support live participation and interaction. In contrast, traditional BPMN modeling environments formalize and analyze processes, and have recently shown an interest towards integrating customer-centric journey mapping with business processes [15], thus coming closer to the process innovation concerns of DT.

Therefore, a key challenge in transforming DT "solutions" into implementable process innovations lies in the disconnect between co-creation management tools and formal modeling environments. DT innovation boards support collaborative ideation but lack formal semantics, making it difficult to trace and structure granular content objects beyond visual navigation panning across empathy maps or idea clusters. Conversely, BPMN tools offer robust capabilities for process modeling and analysis but are not designed to support the weakly structured ideation flows aiming for low-fidelity prototyping and early-stage innovation. This fragmentation across tools results in limited traceability, reduced knowledge management capabilities and a lack of continuity from ideation to implementation, highlighting the need for more integrated modeling methods over these gaps. Hence, this research seeks to address the following Design Science research question**:**

How can BPMN support Design Thinking - what conceptualization gap exists between the two and how can we fill this gap in BPMN tools?

The DSR treatment we are developing is a BPMN-based DSML and an associated modeling tool as basis for a novel modeling method. In order to support the modeler with adequate semantic distinctions (on which model queries for knowledge navigation and reporting will later rely), the DSML adopts as first-class modeling constructs the DT-specific types of activities, events and content artifacts, while relating them as specializations of legacy BPMN elements - to leverage business process modeling familiarity, and to enable traceability in both directions, from work structure to ideation artifacts and vice versa.

Methodologically, the work is grounded in Method Engineering, further specialized in Agile Modeling Method Engineering (AMME) [16] – this approach is typically employed for engineering DSMLs and associated methods in the framework of OMILAB[7], a modeling-focused community of practice. By repurposing process-based reporting and analysis - commonly available for Business Process Management -, and by adapting such features with the help of the ADOxx metamodeling platform, we enable the traceability and retrieval scenarios that can be the foundation for a

[6] https://miro.com/
[7] https://www.omilab.org/

Knowledge Management capability. Both process manifestation levels mentioned in the previous section (the *process of DT* and the *process underlying DT solutions*) are involved and interconnected by a layered conceptualization based on decomposing BPMN task and content flows.

3. Related works

Design Thinking workshops can be seen as participatory modeling sessions where both the method and the metamodel are initially tacit, strongly guided and emergent through DT facilitation. Method steps and domain concepts are gradually revealed in a minimally formal manner, framed by different types of visual items corresponding to different workshop phases. Priority is given to group (guided) communication and content flow, unconstrained creative participation and commitment to selected decisions and ideas. All these should remain unconstrained, i.e. free from any formal modeling procedures, but this does not mean they cannot be complemented by a formal modeling method – to be applied retrospectively by the DT facilitators for their own Knowledge Management purposes. This could be fused together with the digital innovation boards used at "workshop run-time", for streamlining benefits such as those advocated in digital DT tools like Scene2Model [13], but that would be a different focus on human-computer interaction as opposed to our current focus on conceptualizing the DT experience as a Knowledge Management enabler.

Traditional participatory enterprise modeling involves a method expert who guides domain stakeholders or performs knowledge structuring on their behalf, in various collaboration patterns [17]; however, in enterprise modeling there is an explicit and well-formed metamodel governing the modeling toolkit, the model quality, the method expertise and guidance provided to domain stakeholders. These are missing in DT practice where visualization and communication are favored to the detriment of structured modeling, however an important commonality is that DT sessions must be structured according to well defined phases encompassing different content objects, types of activities and expected events. This has been also recognized for participatory modeling [18] and is a central part of the tacit knowledge applied by DT practitioners. Moreover, DT facilitation has elements of "modeling conferencing" [19] - due to how participation is structured - and of "tangible modeling" [20] - due to the prominent use of tangible items (post-its or figurines) to stimulate psychological ownership and commitment to ideas.

The modeling method proposed by our work aims to provide a metamodel encompassing both how the "conferencing" takes place during DT events and the types of content objects being managed there. Therefore, the developed DSR treatment does not aim, at least in early iterations, to be a toolkit for participatory workshopping – but to support the modeling of the work and content flows taking place during workshopping, either *retrospectively* (a repository of what happened) or *prescriptively* (on what should happen, e.g. to train a junior DT facilitator or to plan an event). This is also relevant to the lens offered by Nonaka's knowledge conversion model [21], which currently favors Socialization and tacit knowledge in DT - whereas knowledge repositories to support the other dimensions are still lacking, typically reduced to archival documentation (photos, recordings) or the digital boards where the work was performed in on-line settings. In line with the earlier OMILAB agenda to support Knowledge Management with Conceptual Modeling [5], we aim to fill this gap and enable DT-oriented knowledge management systems via a domain-specific modeling method that captures and renders traceable relevant semantic distinctions in the "domain" of DT.

DSML engineering has been involved in the past in adaptation and customization of process models to better fit user-centered participatory innovation needs [22]. Tangible Business Process Modelling (TBPM) is a significant achievement in extending BPMN with Design Thinking artifacts through physical modeling techniques, where practitioners use tangible objects to represent process elements or context, making process modeling more accessible to non-experts [23,24]. A recent OMILAB contribution to this is Scene2Model[8], a platform designed to digitize physical storyboards

[8] https://scene2model.omilab.org/

through haptic object recognition technology - to associate conceptual modelling artifacts and link them to BPMN models. However, that tool is actually intended for participatory problem modeling during DT workshops and does not expand to the meta-knowledge of the DT experience itself.

Past studies have examined BPMN's extensibility, discussing classes of domain-specific BPMN to accommodate unique industry needs [25], a trend where our work can also be included. BPMN extensions include quality management, performance measurement, e-health, security and many others [26, 27]. This is also being a recurring preoccupation of the OMILAB community with devising process-centric DSMLs – e.g. [28] also addresses knowledge management in terms of the DIKW (data-information-knowledge-wisdom) pyramid. Many of the BPMN extensions surveyed in [25] focus on domain-specific resource classes and follow a descriptive purpose.

The meta-knowledge pertaining to problem solving has also been recognized worthy of modeling through DSMLs in the problem-solution chain modeling approach of [9], however without taking conceptualization input from the DT practice, as it minimally focuses on problem-solution flows. Explicit modeling of DT artifacts and workflows was addressed, besides the aforementioned Scene2Model toolkit, by [29,30] but the purpose was limited to diagrams for visual inspection and did not consider semantic traceability and taxonomies involved in our work. Such past work also neglects BPMN integration – a connection that the discipline of Business Process Management made in the context of process innovation [31], either for monitoring-based methods like Six Sigma [32] or for the Process Redesign Orbit [33]. Knowledge-based methods can be more radical and transformational, relying more on traceability and sense-making than on data - methods like NESTT [33] aim for radical change, questioning the underlying assumptions of current workflows to facilitate disruptive innovation; creative methods such as 7FE [34] emphasize the management of ideation, stakeholder engagement, and exploration of novel alternatives. Therefore, we take a knowledge engineering path to how process innovation is performed via DT, preserving BPMN at the center of our conceptualization.

4. BPMN for design thinking workflows: a reconciliation

Business processes are often obscured in Design Thinking discourse, although they are not absent; vice versa, the traceability to motivation and ideation, is out of scope for a standard like BPMN. It can be argued that BPMN and DT are not directly comparable: BPMN is a formal language governed by an explicit metamodel, whereas DT is a method relying on tacit knowledge – by making it more explicit, a knowledge structure emerges from DT practice and can bridge the gap to BPMN. We believe their synergy can produce an effect towards enabling a Knowledge Management capability, therefore the DSML developed in this work extends legacy BPMN with conceptual constructs derived from experiential insight obtained during Design Thinking events, possibly annotated by quantitative observations similar to those involved in Business Process Management (time, resource consumption).

Process innovation, as typically rolled out through Design Thinking, involves a structured transition from ideation to prototyping. Ideation encourages divergent thinking to generate novel solutions, while prototyping enables iterative validation of these concepts through low-fidelity simulations or mockup process representations. This progression ensures that innovative ideas are both contextually grounded and feasible. Procedurally, DT encompasses five key phases: *Empathize*, *Define*, *Ideate*, *Prototype*, *Test*, and iterates some of them, frequently returning to *Define* or *Ideate* in iterative sessions. Within and between these phases, DT facilitation implies the governance of tides of content divergence (diversification, stimulation of creativity) and convergence (clustering, voting) towards obtaining stakeholder commitments on a limited number of solution propositions - to be evaluated before becoming implementation candidates or tracing back to alternative solutions. This typically follows a back-and-forth workflow and event handling performed by the facilitator based on their tacit knowledge, while advancing through the macro-phases and managing specific content objects – empathy points (e.g. pains and gains), ice-breaking questions, contributed and voted ideas, scenario mockups etc.

In contrast, BPMN prioritizes imperative control flows and data flows but does not consider the DT specificity of task types, event types, data object types etc. For the "DT as a process" level (as formulated in Section 1), past literature typically employed BPMN to design a fixed reference model [8]; instead, we aim to provide a modeling method that extends BPMN into a DSML that allows flexible design of DT workflows. For the "DT solutions as processes" level, modeling support is more common - e.g. in Scene2Model [13] it is possible to link elements of a Process Map to storyboards – but granular semantic traceability is still overlooked: by drilling down the DT work and content flows, "solution process" can be traced back to the pains and gains that motivated their ideation (e.g. from a Persona description), as well as all intermediate stages of ideation and their participants.

Through the design decisions of the proposed DSML we aim to reconcile BPMN with the semi-structured light-handed guidance of the DSR phases and semantic distinctions. Several design decisions are key to this reconciliation, rooted in other modeling methods:

1. The CMMN standard [35] is advertised as being complementary to BPMN's focus on imperative step-by-step execution, but both practitioners and research have shown that BPMN has some less used features to allow a comparable support for more declarative modeling similar to CMMN [36]. Such features are *ad-hoc subprocesses* (sets of tasks whose order of execution is partially specified or left entirely at the discretion of the performer), *boundary events* (diversifying expected situations that may deviate the main process flow) and their combination (boundary events expected during a certain phase of the process, which is delimited as a weakly structured ad-hoc subprocess). These features are prominent design guidelines for the DSML discussed in this paper, with exemplification to be provided in Section 5;

2. The Work System Framework [37] is an enterprise modeling framework that neglects strict control flows, and instead follows a decomposition and drill down principle to "work systems". This is a versatile notion that covers both large scale information systems and granular micro-systems where at least an activity is performed by some participants, supporting by technology and information, to produce a benefit (product) for an internal or external customer. The Work Systems Framework was successfully applied in the past as a conceptualization lens, e.g. for knowledge graphs [38] and we are doing something similar to enrich the proposed DSML.

We employ this notion adding it to our DSML as a specific subtype of ad-hoc BPMN subprocess representing a Design Thinking session or phase – where workshop participants collaborate supported by technology (e.g. Miro) and information (facilitator instructions and input from previous sessions) to produce ideas and commitments for the solution-seeking stakeholders. The Work Systems lens is not fully applied, since we neglect its external viewpoint (comprising Strategy, Infrastructure and Environment) – because these are mostly invariant between DT phases, and therefore not necessarily useful to a Knowledge Management capability – unless a requirement for it will arise in future evaluation;

3. New types of events, tasks and data objects must be reclassified according to **DT-relevant taxonomies**, and some new concepts are added to bridge the gaps between the DT constructs, the Work Systems view and BPMN.

5. Design and development

Figure 1 suggests several concepts gleaned out from the innovation boards of real DT workshops. They become part of the DT metamodel part covering content management. They are content objects distinguishable in the DT practitioner's mental model and innovation boards layout, that we turn into explicit ontological constructs – although a DT workshop would start with a tacit awareness of these, gradually revealed to the participants during the guidance and content structuring effort of the facilitator.

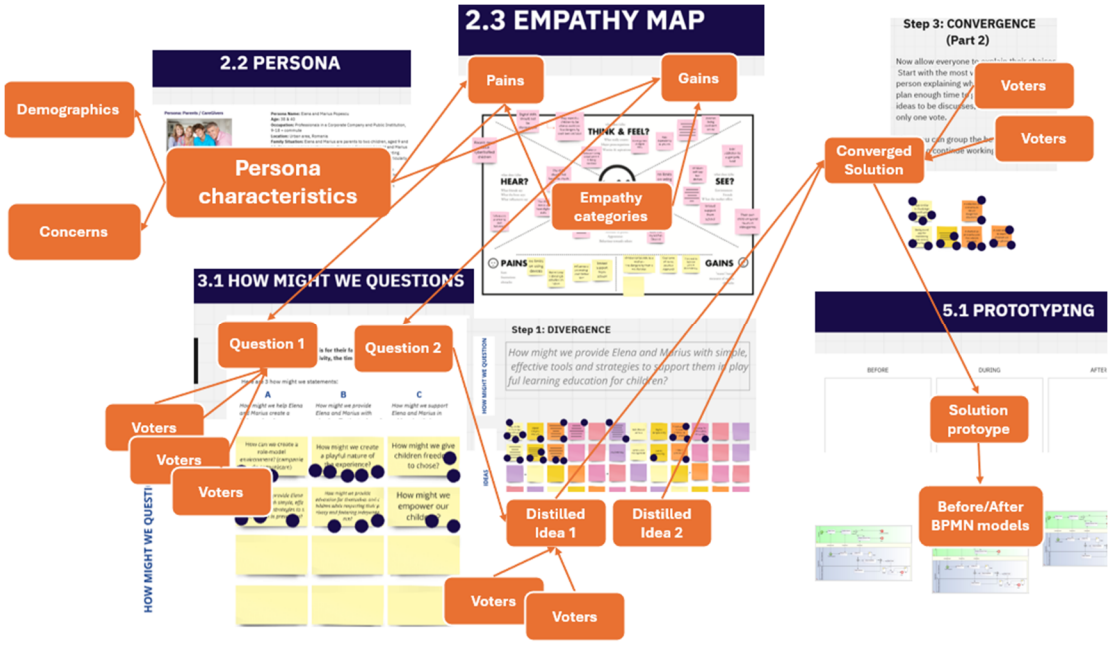

Figure 1. Exemplary items from a Design Thinking digital board from which DT-specific taxonomies have been gleaned

An initial assessment of Design Thinking board templates for tools such as Miro has been conducted - several content objects have been identified as relevant for informing our Knowledge Management treatment, inspiring the taxonomies to be described in this section:

- *Empathy Mapping* – Describes user emotions, motivations, and pain points to ensure that business processes align with real user needs.
- *Customer Journey Mapping* – Visualizes user interactions with a process or service, highlighting friction points, touchpoints and opportunities for improvement.
- *Personas* – Creates fictional representations of key stakeholder classes to better understand their goals, challenges. It is closely associated with *HMW (how-might-we) Questions* that reformulate Pain/Gain points (from *Empathy Mapping*) into more detailed questions that lead to the DT workshop objectives.
- *Brainstorming and Ideation Techniques* – Includes approaches like Scamper[9] and Brainwriting[10] to generate innovative process improvement ideas.
- *Prototyping & Wireframing* – Rapidly develops conceptual representations of new processes or product interfaces to gather feedback on feasibility. These may be complemented by *Storyboarding* – to capture processes in a graphical storytelling manner (the focus of the referenced Scene2Model toolkit [13]).
- *Dot Voting, Clustering & Prioritization Tools* – Helps teams to follow Convergence activities where they focus on and select the most relevant questions, ideas or prototype proposals.

While these have proven valuable in user-centered design and innovation practices, their integration into a domain-specific modelling method remains underexplored.

The visual appearance of the BPMN-based DSML is showcased in Figures 2 and 3 in term of concept specialization taxonomies, and in Figure 4 as a minimal showcase demonstrative example. Many BPMN symbols may be recognizable because the visual elements are largely repurposed by giving them different meanings – this is not a definitive notation engineering decision (and definitely

[9] https://www.interaction-design.org/literature/article/learn-how-to-use-the-best-ideation-methods-scamper
[10] https://miro.com/brainstorming/what-is-brainwriting/

not a recommended shortcut for DSML engineering), but it is a working improvisation for the current iteration focusing on conceptualization and taxonomization – i.e, we postpone visual quality/identity until the conceptualization reaches some stability relative to competency questions we are collecting for the Knowledge Management capability. This is the reason why in the subsequent figures, only a few graphical cues are used to distinguish the new types from legacy BPMN types. In most cases the type/subtype of the element is displayed as a textual prefix to be shown in front of the user-edited label (as noticeable in Figure 2)

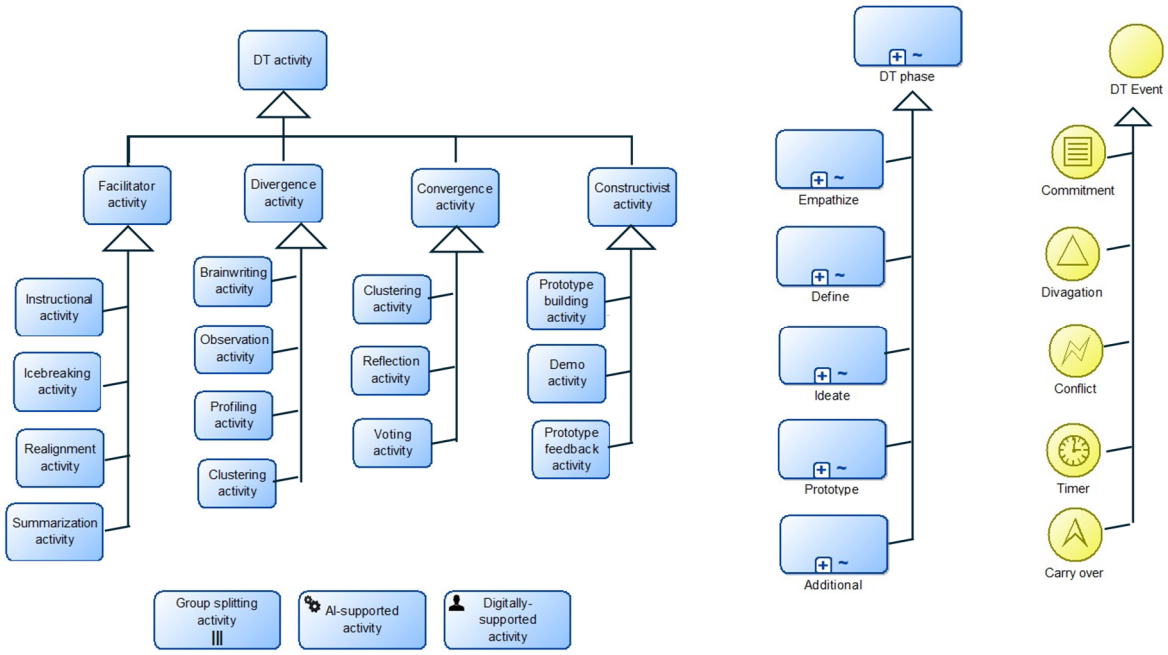

Figure 2. Taxonomies of DT activities, DT phases (ad-hoc subprocesses repurposed as work systems). All notation repurposes existing BPMN icons (work in progress subject to future individualization)

Figure 2 presents a DT-specific taxonomy of tasks/activities, phases and events. The *Activity* hierarchy has a first level distinguishing *Facilitator*-led activities (where the facilitator creates most of the content), *Divergence* activities (where the goal is to collect diverse content from participants), *Convergence* activities (where focus is enforced to narrow down content/contributions), and *Constructivist* activities (prototyping-related). In addition, at the bottom of the figure some repurposed graphical cues indicate an activity that requires splitting of participants in *Subgroups* managing different content objects, *AI-supported* and *Digitally-supported* activities (expected to be associated to technology items in the Work System subprocesses).

The taxonomy of *DT phases* is largely mapped on the standard phase types, plus an *Additional* Phase fallback for any activities that the DT facilitator plans or was forced to improvise.

The taxonomy of *Events* maintains the BPMN distinction between *Start*, *Boundary* and *End* events but interpretations differ: *Commitment* is a typically boundary event closing a phase with some content to which all stakeholders committed, before advancing to the next phase; in the absence of this it means that progress was enforced by the facilitator without necessarily having a hard commitment (possibly to be revisited in future session iterations). *Carry over* refers to pieces of content or tasks that are postponed to future session iterations (i.e. linking to other diagrams detailing other workshops carrying over the postponed aspect). *Divagation* and *Conflict* may be used, in planning how to handle expected topics of conflict or distraction or, in retrospective, how they were actually handled and what exactly was the topic or content object generating the situation. *Timer* has the traditional BPMN interpretation of indicating time-related events (beginnings, waiting states or inability of a task/phase to finish in the planned timeframe).

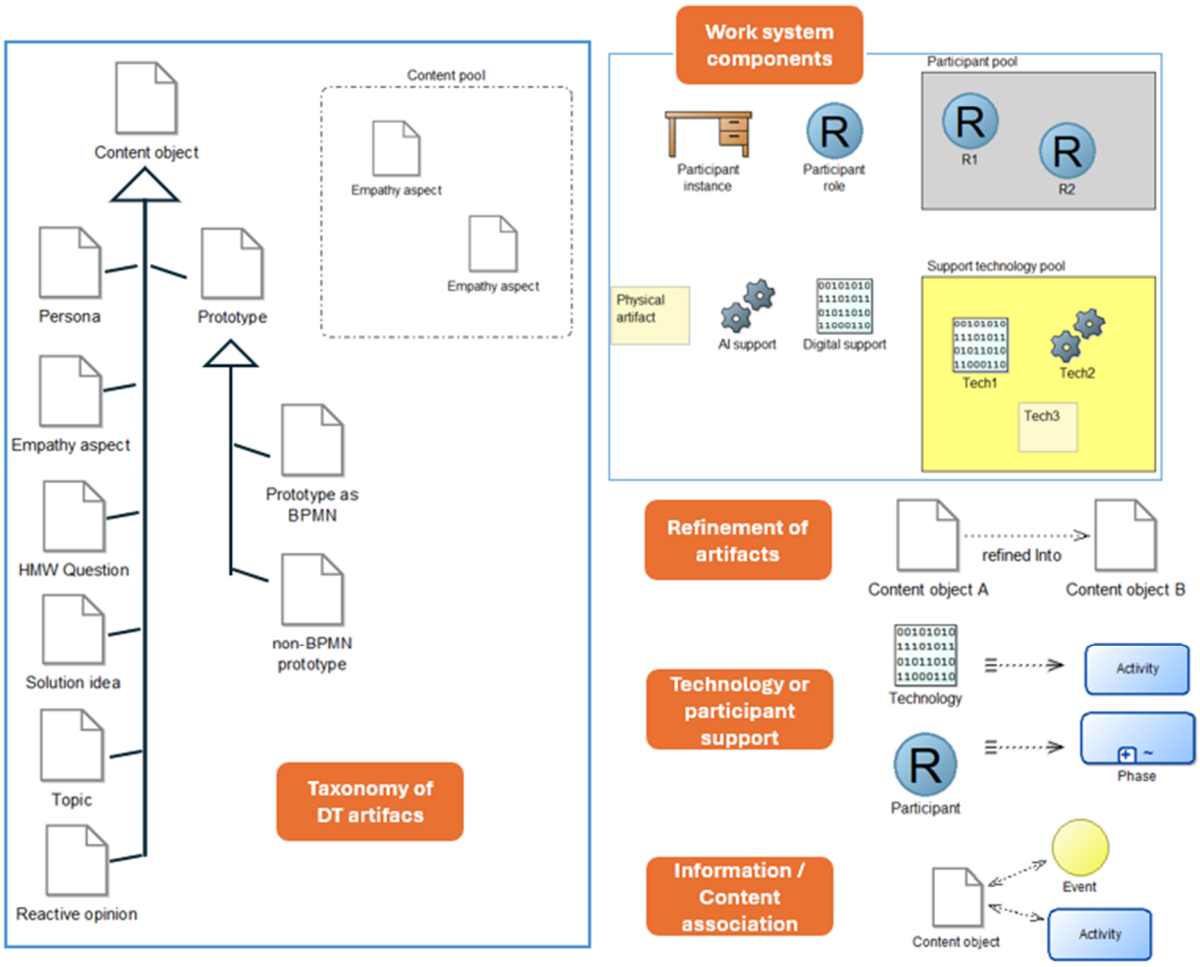

Figure 3. Taxonomy of content objects and Work System internal components (participants, technology, information and associated relations)

Figure 3 shows the repurposing of data object symbols as "Content Objects" specialized in a taxonomy of common DT items/artifacts. They are used similarly to data objects, through data association connectors to indicate input/output (and expressing the "Information" aspect of the Work Systems Framework). A specialized version of the data association ("refined into") may capture the distinct stages of refinement between artifacts within the same phase (e.g. evolution of an idea/question) or between different phases (evolution from pain points to HMW questions, to solution ideas and so on). Also based on the Work Systems Framework, the right side of Fig. 4 shows symbols for participant stakeholders and technology support, completed with grouping containers if a bag of such elements must be associated to a task/phase.

Figure 4 showcases an application example of a diagram depicting what happened in a workshop session on developing solutions for creating awareness of dangers in digital device activities for children of a school. Contributions come from concerned parents and developers of a potential educational app to tackle the problem.

As the diagram expresses, the workshop described with our DSML was supported by digital tooling like Miro and ChatGPT, physical instruments (a Post-it board), involving a pool of participant roles (if they are disconnected, it means they were generally involved in all tasks shown by the diagram). Relevant events visible in the example are the postponing of a Persona (generating a different pathway of divergent problems) and the need to carry over the workshop after not being able to close the Define phase in 2 hours. A divagation on the topic of antivirus tools was steered back in the second Empathizing phase. Phase 1 progressed to Phase 2 without having complete commitments on all content objects produced there, while Phase 2 progressed to Phase 3 with complete

commitments. Phase 2 was organized by splitting subgroups that worked in parallel on Pain points and Gains. Various content objects are visible as inputs/outputs of various tasks and phases.

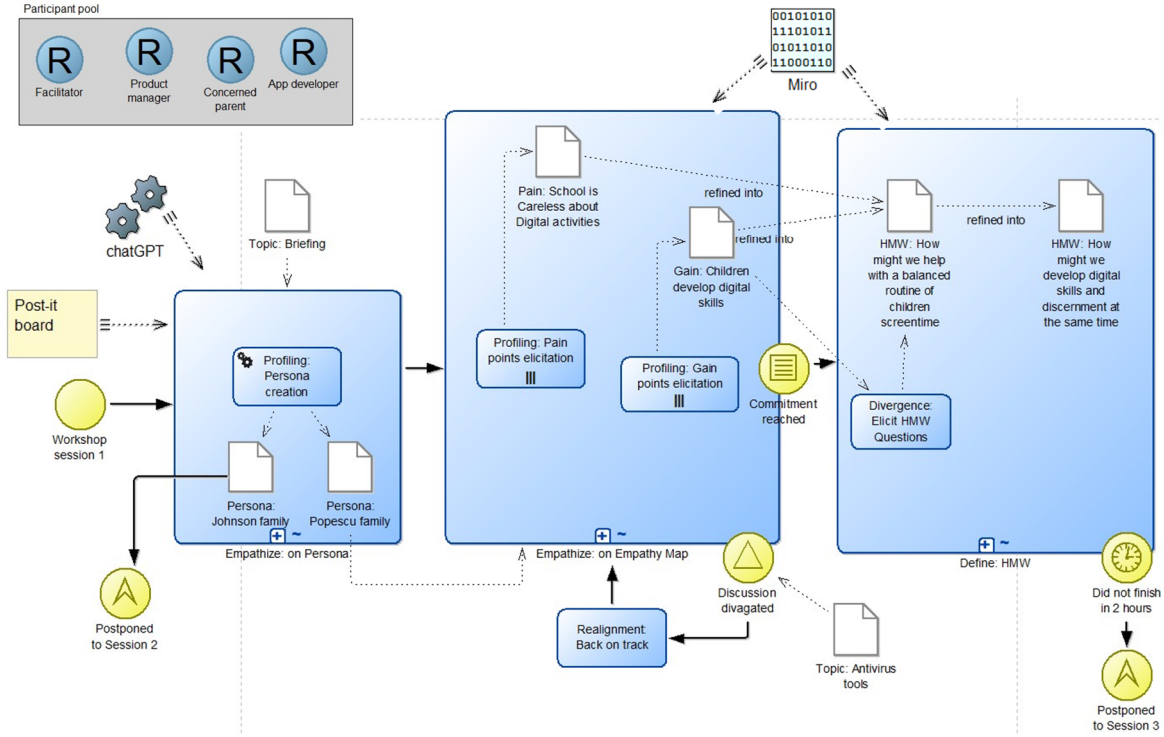

Figure 4. Example of DT workshop execution report with exemplary events, involvement and content objects

Just like in BPMN, the level of detail and specialization of elements to be applied is dictated by the required reporting and competency – which in Business Process Management relies on process querying methods [14]. We adopt and repurpose the process querying engine available in the legacy BPMN tool that was extended for our DSML – i.e. the ADOxx query engine adaptable to all metamodel changes[11], therefore queries benefit from all extensions applied to the BPMN metamodel available in OMILAB's Bee-Up tool[12]. A couple of traceability scenarios are exemplified below:

- Retrieve all content objects that are inside the phase following the Empathize on Persona ad-hoc subprocess:

  ((({"Empathize: on Persona":"Subprocess (BPMN)"}->"Subsequent")<-"Is inside")>"Content Object"<

- Retrieve all AI supported content objects that are inside the phase following the Empathize on Persona ad-hoc subprocess:

  (<"Task (BPMN)">[?"supported"="AI"]->"Is inside")<-"Tech supports")>"AI support"<

Process querying methods, typically used for the Process analysis phase of Business Process Management, will thus be able to navigate and distinguish the DT-specific taxonomies, flows of content and work system drill-downs captured in this DSML. They will identify the desired dependencies and enable reporting on a repository of such diagrams. As we are now in an early-

[11] https://www.adoxx.org/documentation/75_adoxx_development_languages/01_AQL.html#aql-statements
[12] https://bee-up.omilab.org/activities/bee-up/

stage evaluation phase, we are collecting such reporting requirements from DT practitioners, to support us in refining the taxonomies described in Figures 2 and 3.

6. Project plan and future work

6.1. DSR current and future objectives

This research aims to address a knowledge management gap in Design Thinking practice by introducing a modeling method to enable the description of DT work and its mapping to intermediate artifacts or final outcomes. The objectives are divided below into design and knowledge goals, and distinguished between preliminary results and those planned for future work and DSR iterations:

Design objectives

- Develop a DSML that extends BPMN with Design Thinking-specific constructs (e.g., empathy maps, personas, ideation clusters, and prototyping representations). Create a metamodel for DT that captures workshops as work systems in a structured and semantically rich format;
- Prototype a diagrammatic modeling tool for the DSML (future work needed to move visual syntax away from the current improvisation of repurposed legacy BPMN symbols);
- (Future work) Implement process-centric scoring and reporting mechanisms, by repurposing established process analysis approaches.

Knowledge objectives

- Investigate the limitations of current DT tools in supporting traceability, structured evaluation, and integration with process modeling environments;
- Explore how modeling methods can externalize tacit knowledge held by DT facilitators and translate it into reusable knowledge structures and repositories;
- Identify key conceptual constructs and relationships in DT practices that are relevant for formal modeling and knowledge representation;
- (Future work) Evaluate the effectiveness of the proposed DSML in real-world settings in terms of usability, modeling efficiency, stakeholder adoption, and stakeholder-provided competency questions;
- (Future work) Contribute a formal method that bridges creative ideation and analytical modeling, filling a gap in current Business Process Redesign methodologies.

The proposed method aims to fulfil the following **stakeholder goals**:

- For facilitators and analysts, it enables the tracking of ideation provenance and evolution through gradually refined DT phases and artifacts across workshops or projects;
- For decision-makers, it provides visibility into the relationship between DT artifacts and proposed process improvements, leveraging a potentially existing Business Process Management culture;
- For Knowledge Management Systems developers, it offers a DT governance semantic structure that may organize knowledge content and enable DT knowledge management capability.

6.2. Methodology

Due to the artifact-building orientation the general research plan follows the DSR process [11] to ensure a structured and iterative work methodology.

Problem identification & motivation: BPMN is widely used for structuring and optimizing business workflows, but its imperative approach shadows aspects of flexible content flows that are

present in human-centric contributive processes; it also lacks qualitative-oriented constructs such as user motivations and decision-making work systems, which are critical in DT workshops. From the other side, DT relies heavily on a tacit conceptualization and lacks a formal modeling and meta-knowledge acquisition approach necessary to enable a DT Knowledge Management capability.

Definition of objectives for the solution: We propose to bridge this gap with a BPMN extension that integrates Design Thinking principles and constructs to enable the modeling of flexible, semi-structured ideation processes.

Design & development: This is a tool engineering phase following traditional DSML deployment tasks. It relies on the ADOxx metamodeling platform and an open-source legacy BPMN implementation for ADOxx, available in the Bee-Up modeling tool for education.

Demonstration: The relevance will be validated in real-world business scenarios, through iterative workshops wherein the first author working as a DT facilitator will reflect on the work unfolding during such events.

Evaluation will estimate the proposal from different viewpoints, from language quality to process comprehension and expert interviews with business analysts or product managers. Less important is collaborative usability, which is inherited from the ADOxx metamodeling platform and influenced only marginally by the Design & Development decisions. Current focus is on ensuring that relevant competency questions can be satisfied by the content of BPMN-for-DT diagrams.

Communication & iteration: This is the initial attempt at communication of early results and the DSR organization plan for this project. Feedback loops will be incorporated to iteratively improve the DSML for better alignment with industry cases identified for Evaluation.

7. Conclusions

Despite the growing institutionalization of Design Thinking (DT) as a human-centred approach to organizational innovation, a significant limitation persists in the management of its emerging knowledge pertaining both to its process and to outputs. The artifacts generated during DT workshops are typically documented in unstructured, transient formats, including sticky notes, visual boards, or informal repositories. They lack systematic traceability, formal representation, and integration into downstream tasks of retrospective analysis and organizational learning from DT experience. That is, organizations are currently ill-equipped to capture, organize, and operationalize the outcomes of DT in a manner that supports sustainable and traceable process innovation. Against this backdrop, the objective of the present research is to develop a model-driven approach enabled by a DSML that incorporates DT-specific constructs in the BPMN metamodel.

As this work is still in its early stages, there are both technical limitations to this report (e.g. misusing BPMN visual icons with different semantics, until the conceptualization gains some stability) and overarching DSR limitations (no current evaluation with industry DT-driven projects). As an opportunity, the developed method could be streamlined with participatory digital boards used during DT workshops – this would leverage already recorded DT content objects and activities. However, this would require additional technological ingredients to ensure interoperability between the modeling environment and legacy digital innovation board tooling – this is not in the scope of this PhD-level research effort, as we are more interested in engineering and capturing the DT-specific knowledge than the potential productization of the idea for high technological readiness.

Declaration on Generative AI

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

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