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ScienceDirect

Procedia CIRP 109 (2022) 629–634

www.elsevier.com/locate/procedia

32nd CIRP Design Conference

Knowledge Visualization: A Design centered Framework

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Abstract

Visualization is the process of mentally establishing, forming, and acknowledging information and the aptness to externally communicate it. This paper highlights the role that visualization methods play in framing the design thinking process. We present a conceptual framework to showcase explanatory examples of visualization regarding each stage of the design thinking process, identifying its purpose and advantages. Finally, we attempt to suggest the use of visualization within design thinking to assist researchers and practitioners in their design thinking process.

Keywords: Visualization, design thinking; conceptual framework

1. Introduction

Design thinking refers to the integration of designers' tools, methods and perspectives to areas that are non-design focused, such as business, finance, or healthcare to confront critical issues experienced by users [1]. The design thinking process involves collaboration between interdisciplinary teams that aim to solve identified design obstacles and pinpoint underlying issues by empathizing with users through synchronous and asynchronous monitoring and evaluation. In this context, the user is the one that determines the problem statement that shapes and leads to a solution discovery phase. Built on the problem statement, propositions are proposed on how to attain solutions to those issues identified; this is achieved by thinking differently about feasible solutions and then pinpointing more plausible solutions in the second stage [2]. Through these generated ideas and propositions, prototypes are generated through material outputs which allow for testing with the help of unified team members and end users, which ultimately allow for assessment and refinement of the proposed solutions [3, 8].

Knowledge visualization within design thinking is the dynamic and interactive visualization of data as part of the non-direct and theoretical design thinking process. It can transfer crucial design data and strategies efficiently to practioners and researchers [4]. Nonetheless, not a lot of focus has been given to knowledge visualization as part of design thinking given the misconceptions related to the field. As design thinking practitioners have often envisioned the approach in a more linear through a two-dimensional lens [5]. It is possible for design thinking – a predominant stage in the design process – to be more explicit and self-conscious through knowledge visualization [6]. It is more demanding to visualize data through the design thinking process given the complexity of the latter, which incorporates a substantial amount of theoretical information [7]. In this frame, visualization expands beyond solely standing for visual terms – utilizing manual tools such as imaging, sketching or digital design [3, 8]. It leans on these skills and methods for the intent of thinking, brainstorming, investigating, and generating ideas. Quintessentially, visualization is a footpath for design [9]. Nowadays within a knowledge-based economy, practitioners

10.1016/j.procir.2022.05.305

who effectively employ visualization methods are more capable of formulating complex data and transforming it into new novel solutions [10]. Conventionally, traditional design skills, such as sketching and imaging, were key means for generating cognitive links between practitioners' cognizance and external representation. This in return enabled a smoother progression of examination and problem-solving via creative investigation [11]. As these established skills have been confronted with new ICT technologies, the usage of visualization tools in design thinking remains fundamentally implemented with restricted considerations and academic exploration [12]. A few exemptions pertain to the application of diagrams within design thinking [13] as well as the function of visual assistance for the intent of group facilitation [14]. Thus, clear consideration of the various aspects of visual imagery is required, as well as their usage within the different stages of design thinking, the values they carry, and how they impact social, emotional, and cognitive design thinking projects.

The aim of this paper is to contribute to extant research on design thinking in two folds. First through the proposal of a theoretical framework of visualization as part of the design thinking process, and second through taking a look at its application within AI based projects. In this frame of understanding, this paper is organized as follows: Section 2 outlines the key visuals within the various phases of the design thinking process to delineate their purpose and advantages. In Section 3, the research strategies and selection methods adopted in this research are introduced. Then, in Section 4, we provide an overview of future research directions to encourage and inform further research. Finally, in Section 5, conclusions and limitations are identified.

2. Knowledge Visualization Methods

The integration and advantages of visualization has been extensively considered within a wide range of fields, including psychology [15], strategy [16], and knowledge management [17]. Nonetheless, the predominant function of visual reasoning in numerous cases of problem solving has yet to be acknowledged [18]. To better understand how design thinking groups can profit from utilizing visualization methods, it is necessary to appreciate the position of visualization from divergent theoretical angles. The human brain grasps visual data more effectively in comparison to written data; for example, when the same data is presented in both visual and written form (e.g., an image with corresponding legend), performance is increased. This outcome is due to our brain analyzing textual/verbal data and visual data in two separate parts of the brain, according to the Dual Coding Theory [19].

Graphically presenting concepts through a visualization lens provides advantages that enable users to convey considerations and their associations [20] by utilizing both visual and verbal outlets [21], ultimately making the process of building each participants' thoughts much simpler [22] and to recollect the considered themes or topics better [23]. Outlining discourse visually can also assist with overcoming cognitive restraints, for instance excessive information [24] and the limited volume of functioning memory due to cognitive load. Accordingly, visualization enables the unpacking of work memory for the purpose of making room for sense making [25]. Furthermore, it should be noted that visualizations contain the following social, cognitive, and emotional purposes in partnership, which can be beneficial for design thinking teams [26]:

- **Emotional Purposes:**
  - Generating participation and commitment.
  - Supporting shared appreciation.
  - Displaying interdependencies.
- **Social Purposes:**
  - Incorporating divergent viewpoints.
  - Further thorough assessments.
  - Easier recollection.
- **Cognitive Purposes:**
  - Allowing new standpoints
  - Further thorough assessments
  - Easier recollection.

For an efficient handover and the conception of knowledge through visualizations, we need to consider four standpoints, grounded on four questions:

(1) What is the intent of utilizing a visualization approach?

(2) What is the nature of data that requires visualization?

(3) To whom is it addressed to?

(4) What is the most pertinent approach to visualize this indicator?

These prime questions guide us towards understanding Knowledge Visualization perspectives as illustrated in Figure 1 and allow us to construct a framework in relation to design thinking later on in Figure 2 based on these perspectives:

Nature of Function	*Nature of Knowledge*	*Nature of Recipient*	*Nature of Visualization*
Coordination	Know-who	Individual	Sketch
Attention	Know-where	Group	Diagram
Recall	Know-how	Organization	Image
Motivation	Know-what	Network	Map
Elaboration	Know-why		Object
New Insight			Story
			Interactive Visualization

Table 1. Knowledge Visualization Perspectives

Considering this standard comprehension of the significance of visualization, we intend to highlight its purpose more precisely in the frame of design thinking. Thus, the remainder of this paper presents the conceptual framework as well as visualization means for each stage of the design thinking process, comprising its utilities and advantages.

3. Knowledge Visualization Framework

Design thinking can be categorized into a five-step process: Empathize, Define, Ideate, Prototype and Test, and through distilling the outcomes of the associated work in knowledge visualization showcased above, bearing in mind how visualization can assist the principal purpose of each phase.

This synthesis focuses on addressing the ensuing questions regarding each phase of the design thinking process:

- What type of content needs to be delineated?
- What are the intended benefits from utilizing visualization for the purpose of design thinking?
- What are the suitable visualization approaches or systems that can be utilized during the design thinking process?

These three dimensions when aligned to the phases of design thinking, shape the framework for visualization through the lens of design thinking, as presented in Table 2. The proposed framework encompasses several benchmarks for design thinking practice: through the content perspective, the framework delineates the data that ought to be visualized considering the key purpose of that stage, in terms of the benefit perspective it underlines the value to be attained through employing visualization, whilst the visualization methods perspective denotes which means and approaches should be utilized [27].

3.1. Empathizing Stage Application

The purpose of this stage is for practitioners to discern and to be involved with the end user and their unique experiences. In this context, this stage determines the appropriate users as well as their needs, and explores their emotional journey which further ushers all innovation ventures.

To identify the appropriate users, stakeholder maps are created to distinguish the divergent types of users, how they are linked together and within what type of system they function.

- Main purpose: To select appropriate users and determine their background.
- What is signified: Users (e.g., Academics, Faculty members), and the Systems (e.g., Education delivery system) that users (student) are bound by.
- Visualization method: Conceptual figure utilizing size and position for further implication.
- Tools/Medium: Post-it notes, White/Blackboard, Digital Software.

Design Thinking Stages	***Empathize***	***Define***	***Ideate***	***Prototype***	***Test***
Main Purpose	Pinpoint appropriate users, discover their unmet needs, uncover their feelings	Disseminate and distil findings into insights and needs, frame a significant and practical problem statement	Idea suggestion, idea selection	Interpret ideas into perceptible artefact, allow user and team interaction with prototype	Improve the solution, allow user and team to assess
Content Outlook	Participants, emotions, needs,	Findings, insights, needs	Ideas	Idea application	Opinions
Advantages Outlook	Lateral thinking, configuration, level, and perspective switches	Combination of data, insight enabler, simplify synthesis and elicitation,	Assembly space, associate thinking, supporting new outlooks, further thorough comparisons	Generating engagement and involvement, offer encouragement	Filter purpose, documentation
Visualization Means Outlook	Mind map, conceptual map, empathy map of compiled data, stakeholder map	Personas, Venn diagram, matrix, Concept maps,	Deviating: Cooperative sketches, duo mind map, brain writing Converging: Venn diagram Abstract diagrams, matrix	Low resolution prototypes: Sankey diagram, Confluence diagram Sketches, mock-ups, consumer journeys High resolution prototypes: tangible	Feedback form

Table 2. Theoretical Framework for visualization in the design thinking process [27].

At this stage of the design thinking process, it is essential for the practitioner to visualize the participants and end users, for the purpose of making the user setting perceptible and clear and to give context, but not precipitately limit oneself to any design solution. In the context of AI based projects, this is the stage is where data scientists would address users closes to the data to communicate the business opportunity and problem and interpret it into testable hypotheses. Including feasibility, cost, and timeline. The strategic team is required to comprehend the issue at greater level and scrutinize the project context. When dealing with integrated AI systems or neural networks, it becomes essential to tackle numerous challenges, which includes an in-depth exploration of informatics and detecting the issues in analytics.

Whilst textual and verbal data is abstract, visualization allows for making concepts tangible and therefore adaptable. Visualizing the systems and participants as part of the setting is valuable for considering and conferring within team-based projects, who are more prone to discern the focal users and participants to share feedback and critique. Sketching a

participant map enables easy alterations and amendments, which fosters the surfacing of more pertinent solutions and suggestions within the team [28].

3.2. Defining Stage Application

The key intent behind this stage is to disseminate and filter the main findings into insights and unmet needs to explore an identified significant design issue. This comprises establishing a meaningful understanding of the end users and developing practical problem statements. These are guiding statements that identify end users' expectations, wants, and needs, and represents a specific design direction. A strong guiding statement sets the context, and frames the mind and heart of the end-user, motivates the design thinking team, and act as a reference for suggestions.

- Main purpose: To disseminate and transform findings into insights and unmet needs to frame the specific design issue.
- Visualization method: Using conceptual visualization through a defined matrix used as a diagram.

Conceptual diagrams, such as a Venn or Matrix diagram, allow users to scrutinize and distil their findings. The characteristics and attributes of the templates are extracted from the users' data, for instance the performance quality of students and complexity of course material. The visual outlines are utilized through software application [29].

In AI centered projects, practioners try to visualize the data using conceptual diagrams, to check for missing values (and determine how to tackle each of them) and possibly test hypotheses. This stage is comprised mainly by data visualization and hypothesis testing, through constructing visual summaries detailing data, incorporating missing values, categorizing imbalance issues, and trying to detect factors that can be valuable for the problem-based project and beginning to formulate hypothesis. Practioners within AI projects utilize tables and plots to produce a first report or presentation to tell a story in relation to the business problem which are ensued by a summative conclusion and suggestions for next steps. [30]

3.3. Ideating Stage Application

The aim of this stage is to produce pertinent ideas that investigate solution spaces and concentration on the magnitude and variety of suggestions before assessing and selecting appropriate ideas. In the frame of an AI focused project, organizations prepare AI solutions for the problems they are trying to address, through algorithms, techniques, and tools to employ at what stage – machine learning and deep learning are two concepts that fit into the solution. Practioners also check for scalability prior to implementation [28].

The peculiarity of deviating ideas or generating options and its converging stages by electing solutions is crucial to the magnitude, innovation, and viability of propositions. Within the convergent stage, the assessment, selection, and integration of ideas is necessary for the ensuing stages. This stage also embodies the evolution by pinpointing issues that require investigation and development of solutions.

- Main purpose: To allow unrestricted visualization of suggestions for a solution to the identified issue.
- Visualization: The range of rhetorical and conceptual sketches and post-it-notes.

3.4. Prototyping Stage Application

The goal of this stage is to convert ideas into tangible solutions that can be adapted into real world settings. The generation of prototypes within primary steps should be a quick process and is most effective when the element of interactivity is present as the team uses it. Further, prototypes assist with attaining responsiveness, investigation, and examining ideas and receiving stimulation for the intent of understanding how to resolve differences, generating discussions and fail rapidly but economically which can be framed as the solution-building practice.

- Main purpose: To formulate the idea of the application as clear as possible and expect the customer experience to generate response from participants and members.
- Visualization: Symbolic and conceptual sketches.

Prototypes can be classified into high-resolution prototypes, for instance digital imagery, role play and objects, and representations, such as drawings or sketches. Visualization is usually used to draw the setting or context, while the underpinning of the experience can be personas linked with the prototype. The outcome can be either storyboards, consumer journey maps or tangible sketches of processes and applications. It is essential that during this phase, the team generate rapid or rough prototypes which allow for feedback and amendments [25].

Within this stage, design thinkers must use a range of methods to create basic visualizations; for example, post-it notes, note taking to more effective visualizations, such as visual metaphors. The visual representations in Figure 4 bring forth focus and encourage visual memory within viewers, in contrast to text, given that it puts focus on emotional response. The wide array of visual metaphors to be employed is massive in contrast to analytical visualization, as presented in Figure 1 through the Venn Diagram. Ultimately, visual metaphors bring forth emotional reactions from the viewer and are recollected easier [26].

Regarding AI based projects, developing, and testing a full-scale model of the AI solution would be time-consuming. However, designing a few prototypes through visualization and testing them can be a sign of smart design thinking ideology. Visualizing a prototype would be the best approach to save effort and time on any error or lapse detected at this stage. If one prototype is not able to make the cut, it will be easy to move to the other and test it. This will be the best approach to identify the best prototype through visualization and scale it to a fully functioning AI model. The hazard of launching an AI solution constructed without using design thinking visualization is

much greater. Through prototyping, the organization has a lower case accordingly [27].

3.5. Testing Stage Application

The primary purpose of the testing stage is to polish the output through integrating the prototypes in the users' daily lives and assess how they use the proposed prototypes. Through assessment and modification of the prototypes, practitioners can better understand the end-user and improve problem statements further.

- Main purpose: To systematize feedback into four classifications: what does not work, what works, new propositions, and what could be enhanced.
- Visualization: Symbolic and conceptual sketches.

In contrast to standard innovation methods, design thinking practitioners pursue testing their prototypes at early stages with end-users to get insights through assessment and feedback. They then enhance the outputs and construct new prototypes based on the feedback obtained. For this, prototyping and testing ought to be achieved quickly and economically. Visualization has the control to efficiently produce solutions through drawing, sketching or by using notes, bringing forth attention and generating emotional reaction to users to make it easy to give an assessment or to evaluate the outcome of the solution [30].

In AI centered projects, once the team selects the successful prototype, they can incorporate the final AI solution, this includes testing the algorithm and overall, AI technology being incorporated to make it more effective and precise. Whether the solution targets enterprise-level problems or functional ones, the general process is similar. Only the problem level and labor and overall impact would change [29].

Thus, having delineated the primal functions of each stage of the design thinking process and provided an illustration of a visualization means to assist design thinking practitioners within each stage, the final section of this paper tackles the implications and limitations of the study which is followed by a conclusion and recommendations for future work.

4. Information Visualization

There is a predominant link between Information and Knowledge Visualization given that they both aid to visualize various abstraction of data levels. Thus, this section tackles the comparisons and contrasts between Information and Knowledge Visualization.

4.1. Information Visualization Definition

The word "Information Visualization" is not singularly utilized in terms of computer science, for instance it can be used in the context of psychology as "[...] an umbrella term for all types of visualization" [23]. Its methods allow for investigating and developing new insights via visualization of sizable amounts of information [26]. Information Visualization theories are founded on computer graphics, information design, cognitive science, and human-computer interaction. Users are able to investigate data in real time and uncover particular visual patterns through Information Visualization applications. These can be dynamic, interactive and integrate details within context, which means that the user is able to get an outline, which is ensued by the visualized information being condensed through filtering and zooming and finally details are available on demand. It is much more effective to work with Information Visualization methods rather than regular database queries when there is low knowledge regarding the data, given that human perception can recognize information configurations visually which can be difficult to pinpoint through operating on pure data [27], [30], [29].

4.2. Comparisons and Contrasts

Knowledge and information Visualization are both founded on the aptitudes of the human perception system, which is adept to digest visual representations efficiently, however the process and content of the respective discipline vary [30]. The main limitations when it comes to Information Visualization in distinction to Knowledge Visualization are the stern emphasis on computer-based visualizations, whereas other knowledge types such as a database, and non-computer-based visualizations for instance sketches are not taken into consideration [24].

5. Limitations of Visualization Methods

This paper aimed to outline the visualization methods used during the five stages of the design thinking process with the purpose of reporting and backing the reflection of researchers. Limitations appear through the set of illustrations that were apparent to the authors; here, it should be noted that there are other visualization mechanisms within design thinking-based projects. It should also be made clear that those visualization function as illustrative cases and not as the norm. Furthermore, it should be recognized that all five stages comprise convergent and divergent stages and that the touched upon visualizations in the paper circumscribe only one of those two stages.

It is anticipated that through making visualization purposes clearer and highlighting cases for every stage of the design thinking process, practitioners are encouraged to regard and adopt visualizations more consciously. Moreover, we anticipate the generation of a more refined outlook of the existing usage of visuals in the frame of design thinking, and supplement design thinking practitioners with new forms of visuals, in the same fashion as Kernbach and Eppler through integrating the Confluence Dynagram and Sankey Diagrams into design thinking groups [30].

6. Conclusion

Design thinking provides an opportunity for innovation that is human-centered, incorporating initial prototypes and user testing. It is common within business innovators and a focal part of design thinking regarding methods, such as being visual, but also keeping a present attitude, such as bias-to-action, is the usage of visualization. Notwithstanding this importance,

visualization usage, as part of the design thinking process, occurs with slight knowledge or reflections regarding its purpose, impact, and appropriateness to the context and objectives at hand. This, in return, can obstruct the efficiency and progress of design thinking practitioners and their proposed outputs to the pinpointed issues.

This paper has highlighted the use of visual thinking through the lens of design thinking by proposing a theoretical framework and descriptive illustrations for the intent of encouraging researchers and practitioners to be more cognizant when adopting visualization means and better recognizing how the latter impacts the efficiency and innovation of design thinking teams.

Future work should further explore the representation of visualization means using a more detailed approach taking an ethnographic stance by exploring and examining practitioners within design thinking teams. Quantitative exploration may juxtapose diverse types of visualization methods through an investigational setup. Further, the use of novel visualization means, for instance Dynagrams [24], digital knowledge mapping techniques [30] or Navicons [29], could be investigated to improve the efficiency of design thinking. We should also not overlook the communication between corporate partners in the design thinking group which necessitates direct and cleat communication of methods and processes in addition to their value. This facet deserves further consideration and study to better grasp the influence of design thinking within business domains.

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