INTERNATIONAL DESIGN CONFERENCE - DESIGN 2016
Dubrovnik - Croatia, May 16 - 19, 2016.

LOOKING FOR FUNDAMENTAL ELEMENTS OF DESIGN THINKING

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Keywords: design thinking, design methods, design process

1. Introduction

The term "Design thinking" (DT) has attracted the attention of many potential areas of application on the last decade [Dorst 2011], [Kimbell 2011], becoming a new paradigm that promises to bring competitive advantage and innovation. However, the perspective of how DT is seen has changed over the time. Its main core was originated with Simon [1969], on his book "The Science of the Artificial". He clearly explains the difference between the natural sciences logic ("how things are") and the design logic ("how things ought to be"), attaining his attention to the design reasoning patterns. This reasoning, Simon [1969] says, is not limited to designers. On the opposite, it is the core that distinguishes professions, such as engineering, medicine and business, from sciences, even if this essence has been lost through the years. Later, Rowe [1987] labelled the design reasoning for the first time under the title of "design thinking".

According to Kimbell [2011b], the DT research line was broken into three through time. This first one, originated by Simon [1969], continued to be studied as a cognitive style, being proposed for ill-structured problem solving. In this line, many authors dedicated their research to the identification and exploration of the designers reasoning, achieving concepts such as the abductive thinking and reflection-in-action [Rowe 1987], [Dorst and Cross 2001], [Cross 2006]. The second line aims to solve wicked problems. There, DT is mainly seen as a design theory, being covered by authors such as Buchanan [1992] and Goldschmidt [1997]. Finally, the third one is the overview of DT as an organizational resource that aims to bring user-centred innovation and creativity. On the last years, many authors supported this approach, such as Brown [2008], Leavy [2010] and Martin [2010].

DT as an organizational resource became a new trend due to recent popularization efforts, such as those of IDEO [Brown 2008]. Since then, DT has been overrated for applications on product development, but also on management and strategic innovation [Leavy 2010], education [Rauth et al. 2010], social-design [Sklar and Madsen 2010], among others.

From those diverse contexts, some DT methodologies (as they are called in this publication) arose, being slightly different from each other due to their fields of application [Plattner 2010], [Liedtka and Ogilvie 2011], [Stickdorn and Schneider 2011], [IDEO 2015]. Allowing people to choose the most appropriate methodology for a design problem is an adequate practice, since it avoids the process to be stiffened up. This discussion is already a commonplace on the design process[1] literature, since a design process model[2] must be adapted depending on its application environment [Rosemann 2003], [ABPMP 2009]. However, it may be difficult to select the most appropriate DT methodology and to identify when it should be applied in the design process.

[1] Design process is understood as the end-to-end business process for creating value for specific stakeholders.
[2] Design process model represents aspects of the design process [Eckert and Stacey 2010].

It is important to point out that the DT process cannot replace the design process. DT partially supports the design process, being able to perform most of the conceptual phase [Gericke and Maier 2011]. However, the design process is more than just defining the product or service concept. It covers many activities up to the definition of the value chain [Pahl and Beitz 1988], [Ulrich and Eppinger 2012]. It should be highlighted that DT could also be used even in the detail or the production preparation phase, whenever innovation, creativity or problem solving is required. Thus, DT should be seen as an approach to be used jointly with the design process and not as a replacement.
The core of DT was partially identified by Dorst [2011], who wandered between the lines of DT as a cognitive style and DT as an organizational resource, linking both research lines. The author points out that the core of DT is the reasoning pattern behind it, which goes through the following basic reasoning patterns: abduction-2, induction, abduction-1 and deduction. Figure 1 illustrates this reasoning pattern. Since the fundamental core of DT is the reasoning process, it is intrinsically flexible and should not be systematized; otherwise the process flexibility would be compromised.

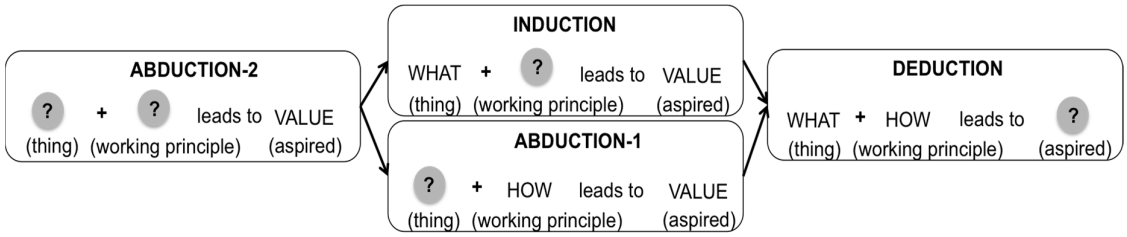


Figure 1. Design thinking (DT) reasoning pattern (adapted from Dorst [2011])

Dorst [2011] strongly criticizes the combination of "vaguely creative activities" under the label of DT, but that is basically what most methodologies seem to do [Plattner 2010], [Liedtka and Ogilvie 2011], [Stickdorn and Schneider 2011], [IDEO 2015]. However, these "vaguely creative activities" could be useful to aid people to perform DT.
The aim of this research is to become a first step towards the identification of the fundamental elements of DT, improving and testing a method that may lead to this goal. In future work, those fundamental elements may complement the DT theory, and may support the exploration of what elements of DT are already used in the design process models and what elements represent the novelty of this approach. It also may support the identification of when DT should be applied in the design process and what elements could be included in each design process model in order to make them more user-centred.
Section 2 presents the element categories that are common to DT methodologies and design process. After that, in section 3, a content analysis of DT methodologies is depicted in order to test the method of identifying the fundamental elements of DT. The test results of the content analysis are in section 4. Section 5 represents a possible relationship that may be used to compare DT elements and design process elements. Finally the limitations, future work and conclusions of this work are presented.

2. Comparison among element categories of design thinking and design process

In order to identify the fundamental elements of DT, it is important to define what element categories are common between DT and design process, since this work is a previous step to explore DT in the design process. Thus, a comparison among element categories DT and the two perspectives under which a design process can be seen (business process and project management) was established. The element categories were partially based on the activity theory principles.
According to Kaptelinin and Nardi [1997], the activity theory is "a set of basic principles that constitute a general conceptual system". Cash et al. [2015] defines activity, task and action in the activity theory as the following:

- Activity: "A goal directed system where cognition, behaviour and motivation are integrated."
- Task: "A logically organised system of actions required to achieve a goal under specific conditions."
- Action: "Discrete parts of a task that fulfil intermediate, conscious goals."

Altogether, activity, task and action assure the description of any period of work [Cash et al. 2015]. This paper will not deepen the concepts of the Activity Theory, since not all of them are necessary for this paper comprehension. Figure 2 shows how the concepts of activity, action and task relate among themselves, including examples inside the design process.

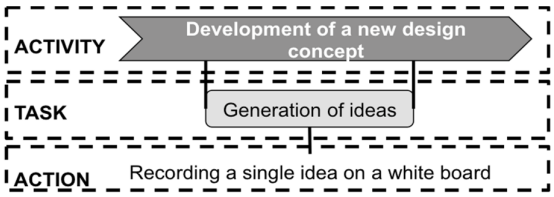


Figure 2. Examples of elements in Activity Theory (adapted from Cash et al. [2015])

In the design process, the process characteristics can be observed from two main perspectives: business process [Cooper 2008] and development project [PMI 2013]. Each one of these points of view is composed by distinct elements.

In the business process perspective, the design process is usually divided into phases that are constituted by activities. Each activity is related to methods and tools, best practices, and resources. The activities are divided into tasks and have inputs and deliverables. Finally, each activity is assigned to different people [Rozenfeld 2007].

In the development project point of view, the activities are defined at the control level. Each activity requires inputs to generate deliverables and can be aided by proper methods and tools [PMI 2013].The DT methodologies are divided in stages that can be classified as activities according to the activity theory. Each methodology prescribes methods and tools. Each method is described in detail, by sentences that could be classified as tasks and actions by the Activity Theory. There are specific people categories assigned to each method in order to transform inputs in deliverables. Finally, each method description proposes guidelines, similarly to the business process best practices.

Now that all element categories in activity theory, business processes, development projects, and DT itself that are important for this work are discretized, their comparison is shown in Figure 3.

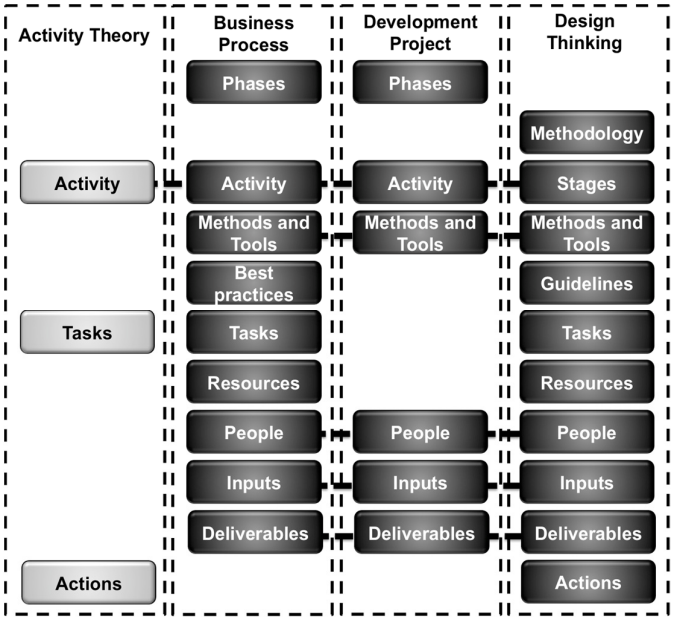


Figure 3. Comparison among the element categories

It is possible to notice that five element categories are common among the design process perspectives and DT: Activity, Methods and Tools, People, Inputs and Deliverables. Thus, those categories shall be used as unit of analysis.

3. Content analysis of DT methodologies

The content analysis is a set of techniques used to analyse communications, such as written texts or verbal speeches, through systematic procedures in order to decode the content of a message [Bardin 2010]. One of the principles of the content analysis is the inference. Analysing a text may reveal more than just what is written, revealing from omitted information until the psychological state of the writer [Bardin 2010]. The scope of this work is limited to the identification of explicitly written elements and inference of elements that are omitted or written by different words.

The Content Analysis method recommended by Bardin [2010] goes through three main stages:

- Pre-analysis, where the researcher assesses many sources of information in order to establish the hypotheses and goals of the content analysis. In this stage, the researcher also defines what documents constitute the corpus of analysis and the rules of cutting, categorization and codification. It also may include the formulation of a thesaurus.
- Material exploration, where the techniques of cutting, categorization and codification are applied to the corpus.
- Synthesis, when the researcher performs the statistical operations, jointly with the results synthesis, selection and interpretation. In order to make the statistical operations more visual, a composed Domain Mapping Matrix (DMM) was created. The DMM is "a rectangular matrix that shows the relationships between two domains" [Eppinger and Browning 2012]. The DMM has its origins on the Design Structure Matrix (DSM) theory, where DSM is a matrix capable of delineating the relationships among the elements that compose a given product, a service or other applications, such as social systems [Eppinger and Browning 2012]. In the proposed method, as many DMMs as the amount of methodologies included in the analysis are to be composed, relating tasks (a more proper explanation of why tasks were included in the analysis is offered in subsection 4.1) and methods. Then, the DMMs should be mathematically transformed into a DSM relating tasks with tasks, showing quantitatively how many times each task is performed on all methodologies and how many times each task is conjugated with other given tasks. With basic statistical operations, the fundamental tasks can be identified. It is also proposed that the final results of this analysis should be submitted to assessment of an expert in order to identify whether important elements were left aside. However, the DMM of this paper is an adapted version of the comparative method proposed by Rosa and Rozenfeld [2015] in order to perform a test of the method. In this work, the authors call it a "composed DMM" for it is composed by 3 DMMs. The first part of the DMM shows the relationship between DT methods and the people that should perform them. Whenever a person of index "x" was detected inside a method of index "n", the matrix element E(x,n) received the value 1. Otherwise, it received the value 0. The second part of the DMM shows the relationship between inputs and methods and the third part relates deliverables to methods. The same filling procedure of the first part was used, changing the person by input and deliverable, respectively. One schematic of the composed DMM is illustrated on Figure 4. Findings of the matrix analysis are summarized on the next section.

		People				Inputs				Deliverables			
		P1	P2	…	Px	I1	I2	…	Iy	D1	D2	…	Dz
Met1	M1	1	0	…	0	0	0	…	0	1	1	…	0
	M2	1	1	…	0	1	0	…	0	0	1	…	0
	M3			…		0	1	…	0	0	0	…	1
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Metm	Mn	1	0	…	1	0	0	…	0	1	0	…	1

Figure 4. Schematic for the DMM composition

4. Results

4.1 Pre-analysis

The pre-analysis of this work selected three methodologies based on representativeness and diversity of the fields of application[3]. The first methodology, proposed by the D.School [Plattner 2010], has a generic background. The second methodology comes from the business approach [Liedtka and Ogilvie 2011]. The third one has its origins in the service design [Stickdorn and Schneider 2011].

The first element category that must be analysed according to section 3 is "activity". All three methodologies are divided in stages (or steps). Although each author uses a different label to refer to each one of them, the generic goals of the stages are the same, as shown in Figure 5. The activities of the DT process (also known as stages) are too high-level and common among the methodologies, thus a deeper analysis was considered unnecessary.

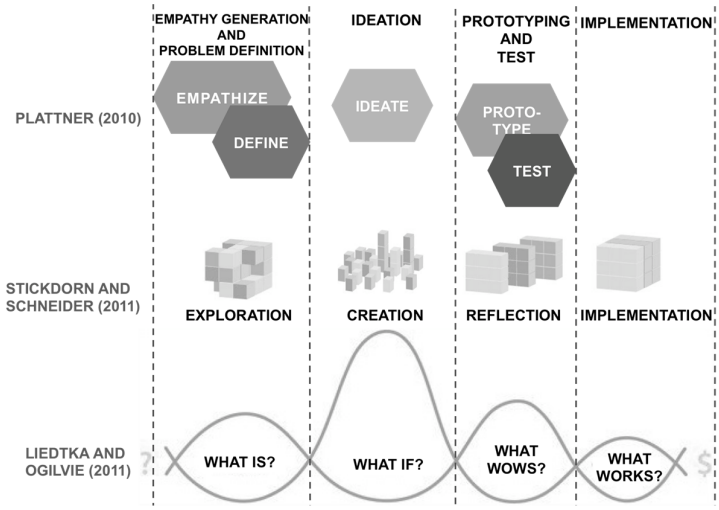


Figure 5. Comparison among DT methodologies phases (adapted from Plattner [2010], Liedtka and Ogilvie [2011], and Stickdorn and Schneider [2011])

The second element category to be compared is "method". The methods presented by each author are highly different. Each methodology shows, respectively, 42, 14 and 25 methods, while only 6 of the methods are common to all methodologies. Among those 6 methods, two are not even cited separately by two of the authors, being included in the description of other methods. It obviously happens due to the different backgrounds of each methodology. Thus, it would be useful to analyse methods by their description, which is commonly in the shape of a sequence of tasks that should be followed in order to reach the goals of each method.

The other element categories to be analysed are people, inputs and deliverables. When analysed alone, elements of those categories lose their meaning. Thus, they should be analysed within their context. Tasks are elements that combine people (subject) and inputs/deliverables (object) by connecting them through a verb. Thus, combinations of subject (people), verbs, and objects (inputs or deliverables), composing tasks, describe each DT method, therefore connecting all remaining four element categories. Whenever these combinations represent an effort, they were considered tasks. Other combinations with the same structure that did not referred to an effort were considered guidelines, which will not be analysed deeper in this paper. Thus, verbs were also treated as fundamental elements to be identified.

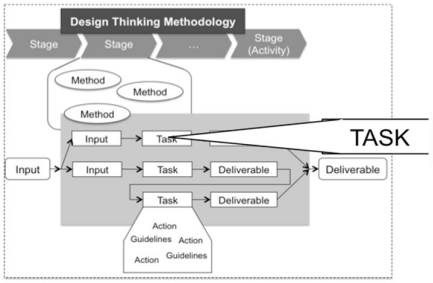
A thesaurus was created during the analysis, being improved whenever a new person, input, deliverable or verb appeared on the text. Each new element that was identified received a common code used for it and its respective synonyms. Due to space limitations, the thesaurus containing codes and synonyms could not be presented in this work. It is important to highlight that a deep analysis was performed, verifying if different words had the same meaning and identifying if the same word had different

[3] As mentioned in section 7, other DT methodologies will be analysed in future work.

meanings in the context. Verbs were the only elements present in the thesaurus from the beginning. A list of verbs was pre-set based on the 27 generic engineering design activities proposed by Sim and Duffy [2003], who identified and classified generic design activities of the design process literature, aiming to provide common understanding about design activities. Although there is a difference in the level of the efforts (activities x tasks), the authors of this paper worked on the hypothesis that activities and tasks would share most verbs. This hypothesis proved to be true, since only 8 of the 27 verbs did not appear in the tasks description. They did not cover all possible verbs though. New verbs were added according to the necessity. The rules of cutting, categorization and codification were also instituted and tested.

4.2 Material exploration and synthesis

The analysis of the elements collected in the corpus for testing was performed, achieving the results illustrated in short in Figure 6. When all elements of all methods in the three methodologies were gathered, a big number of different subjects (people), verbs and inputs/deliverables were identified. However, when the synonyms were united under the same code at the task level, the number of people categories fell 80%, while the verbs fell 83,2% and the inputs/deliverables fell 58%. A number of 213 distinct tasks were identified. Another analysis was performed at the method level in order to identify only the main inputs and deliverables, since the task level also deals with intermediate deliverables. At the methods level, the number of inputs/deliverables fell 87,3% and the number of people categories fell 40%. The number of people categories at the method level was bigger than the task level because the authors of this work separated distinct stakeholders and team compositions in distinct categories for the method level, while in the task level they were all labelled, respectively, as stakeholders or team. However, in the end, the same four people categories used at the task level represented 94,4% of the recurrences. Thus, this discretization did not bring meaningful results. Due to the great amount of data analysed, it is not possible to show the complete results. However, a summary of what was obtained is presented in Figure 6. The authors expect that in future work, when more methodologies are included in the analysis, the number of people categories, verbs and inputs/deliverables shall stagnate, since most of them will have been already detected in other methodologies.



	People	Verbs	Inputs/ Deliverables
∑ Methodologies	20	196	317
Uniting synonyms under the same code	4	33	133
Uniting synonyms on method level	12 (4*)	X	40

Figure 6. Results of the content analysis

It was already explained that the authors of the studied methodologies [Plattner 2010], [Liedtka and Ogilvie 2011], [Stickdorn and Schneider 2011] present different methods among their works. However, even the common methods are described in distinct ways. For example, all authors prescribe the Journey Map method, even if under different labels. Although it is a common method in the user experience literature [Westbrook et al. 2007], [Brugnoli 2009], [Mangiaracina et al. 2010], each author describes the method with the necessary adaptions to her/his environment.

All proposals of applying the Journey Map reach the final goal: describing the experience process. However, each author has her/his peculiarities. The resumed analysis for those three descriptions is illustrated on Table 1. It is important to highlight that sometimes an input is also a deliverable. It happens whenever the method improves a lower-resolution input to an improved deliverable.

Table 1 shows that it is essential to identify the user experience in order to generate the experience process. However, the first two methodologies also claim to deliver motivations, insights and behaviours. They demand more information though, such as the users' speech (interview quotes).

This matrix was assembled for all methods. In order to determine the most important inputs and deliverables, the 20 most recurrent inputs and deliverables were listed, as shown in Table 2.

Table 1. People, inputs and deliverables for Journey Mapping

	People				Inputs							Deliverables															
	Facilitator	Team	User	Problem-solving teams	Emotions	Motivations	Synthesis of observations	Insights	User Experience	Media of the field	Interviews quotes	Emotions	Motivations	Synthesis of observations	Insights	Behaviors	User Experience	Scenarios	Users (who are)	Thoughts	Needs	Ideas	Traits	Experience process	Archetype	Low-resolution Prototypes	Solution principles	Testing Scenarios
Plattner (2010)	1	1	1	0	0	0	1	0	1	0	1	0	1	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0
Liedtka e Olgivie (2011)	1	0	1	1	0	0	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Stickdorn and Schneider (2011)	1	1	0	0	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

Table 2. Most relevant inputs and deliverables

#	Inputs and Deliverables	#	Inputs and Deliverables	#	Inputs and Deliverables
38	Insights	16	Emotions	13	Tests Feedback
27	User Experience	16	Low-resolution Prototypes	13	Concepts
26	Ideas	15	Media of the field	12	Traits
21	Behaviours	15	Thoughts	12	Problem statement
20	Needs	15	Speech (interview quotes)	11	Experience process
19	Motivations	13	Synthesis of observations	11	Design criteria
17	Users (who are)	13	Assumptions to be tested	…	Other deliverables

One aspect that should be highlighted is the low relevance of the user archetype on the deliverables list, which does not even appear on the 20 most recurrent ones. The user archetype is the main result of one of the most cited tools in user experience literature: the persona [Blomquist and Arvola 2002], [Grudin and Pruitt 2002]. Even if the persona is not specifically recurrent, the most relevant deliverables clarify the great importance of understanding users/stakeholders in the DT process. Most of the deliverables on the list are characteristics of the users/stakeholders, such as user experience, behaviours, needs, motivations, identification (who are the users), emotions, media of the field (pictures and video), thoughts, speech (interview quotes), tests feedback, and traits. It means that 55% of the most recurrent deliverables are characteristics of the users/stakeholders that must be identified.

It is clear that the most relevant deliverables are the insights. They seem to be the greatest goal of most methods and are, in fact, essential to the DT process. They are fundamental to create innovative and relevant ideas, which are almost as recurrent as the insights. Another surprising point identified within the results is that the most cited author, Plattner [2010], doesn't work with concepts, but with ideas. The practical experience of the authors of this paper show that it is not a good practice, as reiterated by Liedtka and Ogilvie [2011], who affirm that the ideas are too raw to be directly applied and should be reworked by combining ideas into concepts. However, according to Cunha et al. [2014], ideas may be treated as a generalization, possibly being referred to with the meaning of concept. Thus, it is not possible to know if Plattner [2010] refers to the ideas in their raw state or to concepts.

Lastly, the importance of building low-resolution prototypes (objects, scenarios, storyboards, drawings) and testing with stakeholders them must be pointed out. The low-resolution prototypes are used in order to build to think. When they are tested with users/stakeholders, the feedback provides opportunities for improvement and risk identification.

When analysing the involved people categories, the four most recurrent ones were selected, as explained before. They were the Facilitator, who was cited 71 times; the Team, cited 69 times; the Users, mentioned 19 times; and the Stakeholders, referred to 11 times.

The list of the most relevant people categories for the DT process emphasizes the importance of the teamwork, as well as the importance of the facilitator on the DT process. It is worth to mention that the facilitator rarely is directly referred to in the methods. It was considered that any time that pre-setting a template or explaining a mind-set or the procedures was necessary, so was the facilitator. The same happened with the team. The need of a team was rarely explicitly written, but the main directives of each methodology made it clear that teamwork was essential for the DT methods. Thus, every time that no person is referred to in the method description, such as members individually or stakeholders, it was considered that the method required teamwork. The facilitator being cited more than the users does not mean that users are less important than the facilitator. It only means that the facilitator and the team perform more tasks than the users and stakeholders.
Another characteristic is the continuous reference to users, forgetting to mention stakeholders most of times, even if users are one type of stakeholders. It may be a sign of directed thoughts disciplined to believe that only focusing on user needs is enough. The design theory has already shown the great importance of reaching the stakeholders' requirements in the design process [Sharp et al. 1999].

5. Establishing a first relationship between DT and design process

Based on the element categories comparison, it was possible to identify one way to align the DT practices to the design process. As it was seen, all DT common element categories are related to the task level. In fact, the design process models usually detail the activities by using tasks [Rozenfeld 2007]. The design process tasks, on the other hand, are usually derived from methods that aid the execution of activities. Furthermore, tasks can be seen as a combination of people, verbs, and inputs or deliverables. This way, identifying the fundamental tasks of DT may ease the comparison among DT methodologies and design process models, as illustrated in Figure 7.

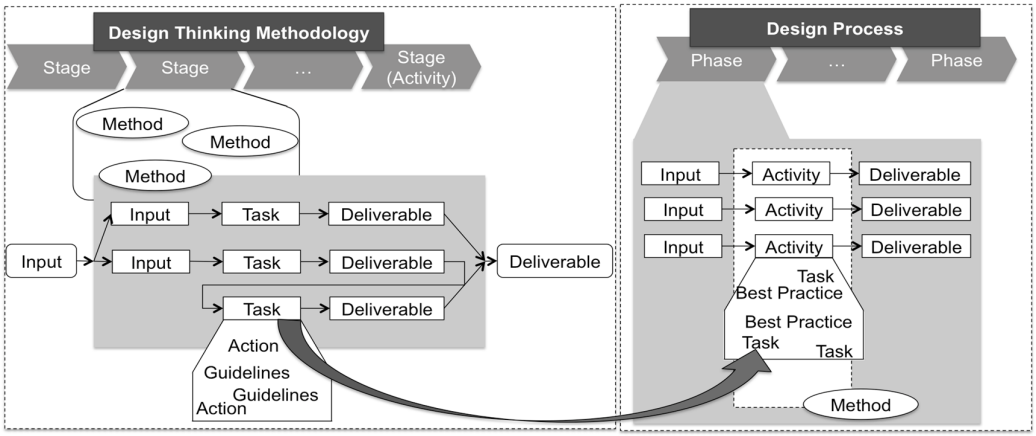


Figure 7. Schematic of the relationship between DT and design process

Therefore, the basic step to support this framework is to define fundamental elements of DT, which can be matched with element categories of design process models.

6. Limitations

Some factors should be pointed out as limitations of this work. First of all, only three DT methodologies were analysed. This may compromise the validity of the data obtained due to sample insufficiency. However, the three methodologies show great background diversity, granting the quality of the sample. In future, more methodologies shall be included (see section 7).
Another factor is the validity of the methodologies used. The D.School methodology [Plattner 2010] is recognized all over the world, being associated to the ME310 course, which was created by D.School and is offered by many universities worldwide. The "Designing for Growth" methodology was written by Liedtka and Ogilvie [2011], two well-known DT researchers of University of Virginia. Finally, the methodology of Stickdorn and Schneider [2011] was written with contribution of 23 names of the DT

literature, some of them with much research in the area, such as Kimbell [2011, 2012]. However, none of the books are scientific publications nor are corroborated by publications of the authors. The decision to use books was taken because the description level in papers is usually reduced when compared to books and guides.
Finally, the method proposed in this work may lose information, since not necessarily an important element of DT will be cited many times. However, an expert shall assess the final results by pointing out fundamental elements that were excluded and non-fundamental elements that were included.

7. Conclusions and future research

This paper fulfilled its main goal of becoming a first step towards identifying fundamental elements of DT. The test results obtained so far indicate that the goal of identifying the DT fundamental elements may be achieved. Although the analysis was not performed with tasks, the elements that compose a task were analysed. The people categories and inputs/deliverables that were identified really seem to report to fundamental aspects of DT.
For future work, the authors expect to include more methodologies in the analysis in order to identify a complete set of fundamental elements of DT. Although the core of DT is the reasoning process, the fundamental elements of DT methodologies will support the synergy of two approaches of different levels of detail: DT and design process. The main relationship between DT and the design process was identified, showing a clear connection among some element categories, such as methods, people, inputs, deliverables, and, most of all, tasks. The tasks allow the connection between DT and design process following the well-establish pattern through which the design process models are already displayed in literature. This relationship shall guide future work on this line.
Typical aspects of DT could be inferred with this test, leading to a belief that the method is able to properly identify the fundamental elements. First of all, a user-centred reasoning process such as DT must involve teamwork, the users and stakeholders, and a facilitator to guide the participants through the methods. Secondly, the main deliverables that must be found in this process include not only the knowledge about the users and stakeholders' characteristics, such as traits and behaviours, but also the understanding of the experience process, besides ideas and concepts generation, prototypes to turn thinking into physical, and tests to validate the results.
It was not thought to systematize and impoverish DT by limiting it to fundamental elements, but to contribute to the design theory by characterizing the DT approach and by allowing design process models to be more user-centric with DT elements that lack in typical design process models.

Acknowledgement

This work was supported by the São Paulo Research Foundation (FAPESP) under the process 2015/00291-0. The opinions, hypotheses and conclusions or recommendations expressed in this material are responsibility of the authors and do not necessarily reflect the perspective of FAPESP.

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