EXPLORING THE SYNTHESIS OF INFORMATION IN DESIGN PROCESSES – OPENING THE BLACK-BOX

Raja Gumienny, Tilmann Lindberg, Christoph Meinel
Hasso Plattner Institute, Potsdam, Germany

ABSTRACT
Information synthesis is an important part of design processes as it ensures to integrate, organize, filter, and evaluate essential information and constraints for the design solution. However, there are various methods, conditions and characteristics of synthesis and it is surprising that little research has focused on this subject yet. In this paper, we outline different approaches to information synthesis and report on our findings from interviews with designers in educational and corporate environments. From these findings we derive a framework in which we suggest to describe the characteristics of information synthesis via the chosen design paradigm as well as ten particular research perspectives. We regard this framework as a basis to understand information synthesis in greater detail and to show possible fields of future research. Additionally, it allows deriving insights how inexperienced designers as well as people from other domains being involved in the design process can be supported.

Keywords: synthesis, sensemaking, framing, information analysis, design paradigms

1 INTRODUCTION
All successful design efforts include the collection of different kinds of information – information which helps to understand users' needs, stakeholders' interests and possible limitations of the solution. Integrating this information in the design process is important – for a viable design and for generating acceptance among the stakeholders of a design process. This practice of integrating, organizing, filtering and evaluating external information is what we call the *information synthesis* in design. We draw in particular on two authors to define this understanding:

> *Jon Kolko (2010):* "Synthesis is an abductive sensemaking process. Through efforts of data manipulation, organization, pruning, and filtering, designers produce information and knowledge." [1]

> *Antony Robinson (2008):* "Synthesis can be defined in a variety of ways, [..] we define it as the stage of an analytic process in which analysts organize and combine individual analytical results into coherent groups that are used to assign meaning and/or encapsulate complex ideas." [2]

Although nobody explicitly denies the importance of information synthesis, it also has not been a major focus in the past of design research. Much has been written about brainstorming, brainwriting and other diverging techniques in design [3-5], but the conversion of information – though a major part in recent design process models [6,7] – has not been in focus of a comparable amount of publications. Only in recent times, some authors addressed the importance of this topic [1,8]. However, research on information synthesis in design has remained fragmented.
This is in our perspective a serious gap in design research, revealing a discrepancy between the importance of information synthesis in design practice and a lack of general knowledge about it. In particular within the presently dominant human-centered design paradigm [9], the synthesis of user research data is a decisive point in the design process, as it decides in what quality such external information flows into the design outcome. Realizing a good fit between external knowledge and the internal process of designing has also become one of the main factors for the market success of a design outcome [8]. Yet, information synthesis is also a difficult and cognitively extremely challenging part of the design process. Filtering, organizing and sense-making of uncertain and ambiguous information is complicated and exhausting [8]. Working in a team can give assistance and can be valuable for the following steps in the design process, but it also introduces the difficulty of

creating a common ground and making decisions all team members support. If team members are not working at the same location or cannot meet due to scheduling problems, it is even more difficult. In addition to those internal difficulties of synthesizing, the communication of its results is similarly complex. In particular when reporting to client and superiors, design teams are oftentimes asked to show how user research has influenced the design process so as to give reason for time-consuming and costly user research activities. A reason why this can be troublesome is the missing visibility and tangibility of the synthesis phase and the high amount of tacit information involved. In contrast to later parts of the design process in which designers can easily show some artifacts or concept drawings [1], the complex knowledge of user research can only be made communicable to external persons by means of a purposeful information synthesis.

Given such challenges it is surprising that the synthesis of information still remains a "black box" in design research. Therefore, the major concern of this paper is to direct the attention stronger on information synthesis as a crucial field of research. As a contribution to this, we will present different perspectives on synthesis research in a comprehensive framework, which we developed out of a combination of primary and secondary research. We will show different approaches of how people deal with the cognitive challenges and what strategies they developed to solve them. This shall outline the basic perspectives on synthesis research and stimulate further research.

2 LITERATURE OVERVIEW

There are two different main concepts of synthesis in design theory. Some authors use this term to refer to all activities of assembling or creating the form of the design solution – in contrast to the term *analysis* referring to the activity of investigating and defining the design problem [6,10,11]. In the other understanding, the term is used to mean what we call *information synthesis*, that is the process of condensing and framing information as a part of the problem understanding activity in design processes [1,2,7,12]. In other related work, this understanding of synthesis may be referred to by the terms *framing* [8,13] or *sensemaking* [14].

The state of literature about information synthesis is rather fragmented. Kolko is one of the few authors focusing on information synthesis in design as such [1,15]. He develops both a theoretical overview on and methods for information synthesis [15]. Hey et al. [8] address similar notions, though they do not use the term synthesis but *framing* instead, which they connect with the process of generating a shared understanding among the members of a design team.

Related work outside design research can also be found within the fields of management studies and social science, though employing terms like *information analysis* [16], *collaborative synthesis* [2] and *sensemaking* [14] [17] instead. In particular, research by Robinson [2] and Isenberg et al [16] is of interest, as their observations of teams synthesizing information as part of problem solving processes allow drawing parallels to information synthesis processes in design teams. Another group of related research focuses on theoretical frameworks on sensemaking [14] [17] in order to develop basic assumptions for the development of digital tools supporting information synthesis. Further work presents already developed tools for sensemaking [18] and decision making [19], whereas these publications rather focus on the usability and adoption of tools and not so much on the theoretical issues behind [20].

Literature on discursivity, communication and knowledge use in design teams is also relevant, although such literature rather addresses design processes as such and thus do not necessarily show specific reference to activities of information synthesis [13,20-25]. However, we regard such research as insightful for our purpose as it allows initial insights about how dynamics behind team communication can influence the condensation and framing of information.

3 RESEARCH QUESTIONS AND METHODOLOGY

As described in the introduction, this paper's goal is to develop a comprehensive framework for research on information synthesis. Within this framework, we plan to distinguish between different research perspectives as well as hypotheses to be explored in further studies. To develop this framework, we draw in particular on two guiding questions that help us to address both a) the fragmented state of knowledge on information synthesis and b) the diversity of and the various challenges embraced by design processes as such, namely:

a) Which different forms of information synthesis in design do exist? How do people proceed while synthesizing and what is their objective of the synthesis?

b) How do people deal with the different challenges of information synthesis in design? Which problems do they encounter and which strategies do they choose to come to a result? How can we support them in this phase?

We chose a twofold research approach, combining primary (expert interviews) and secondary data (literature analysis): We built upon a comprehensive overview on the state of literature and developed insights according to our research questions (secondary analysis). In addition, we conducted expert interviews with design teachers, professional designers and design students, that all have made experiences with information synthesis in design processes. The interview length varied between 20 to 45 minutes. We used interview guidelines focusing on how people condense, select and decide when synthesizing information and how they evaluate the approaches they employ. All interviews were taped with a voice recorder. To analyze and frame the research data, we drew on grounded theory methodology [26]. For each interview, we wrote various memos on sticky notes and clustered them firstly on separate boards and analyzed afterwards similarities and differences between the interviews iteratively. At the end, we developed our framework by comparing and combining the interview results with the results of the literature analysis.

4 TOWARDS A FRAMEWORK FOR INFORMATION SYNTHESIS RESEARCH

In order to work out a framework for information synthesis research, we proceeded in three steps. First, we distinguish between different paradigms of designing that can influence not only the entire design process but also the character of information synthesis as such. Second, we develop different perspectives on information synthesis that help to explain and to distinguish its characteristics and allow further, more detailed views. Third, we assemble paradigms and perspectives to a two-dimensional framework and use this to work out a structured pattern of hypotheses to guide forthcoming research on information synthesis.

4.1 Design paradigms

Design paradigms influence the whole design process and thus mainly affect form and proceeding of the information synthesis. In design theory, in particular two opposing paradigms are often discussed: the *scientific/rationalist* design paradigm and the *reflective practice* paradigm [27,28]. The scientific or rationalist design paradigm originates from the analytic-positivistic framework of science. Design is seen as a rational problem solving process [27], in which problem definition and solution development generally occur in a linear sequence. Thus, as in science, one assumes that a problem is eventually definable and processes of iterating and problem reframing rather indicate weaknesses in a design process. Also, designers following this paradigm are generally dependent on explicit and unambiguous information. The reflective practice paradigm refers to Schön's concept of the designer as a reflective practitioner [29], even if some ideas go back to Rittel's concept of planning in the context of wicked problems [30,31]. The basic assumption of this paradigm is that the ambiguous quality of design problems cannot be addressed by scientific methodology, but with a rather explorative and subject-driven approach that Schön calls "a reflective conversation with the situation" [29]. However, on closer examination, we realized that this paradigm can be divided in two different ones, dependent on what the designer perceives as constituting the situation of the design problem. On the one hand, there is the currently very popular *human-centered* design paradigm, according to which the situation of a design problem is mainly constituted by stakeholder (i.e. user) perspectives. Thereby the rather tacit human-centered information is a key component of design processes [9]. On the other hand, there is the *authordesign* paradigm, according to which rather the subjective experience of the designer gradually constitutes the perception of the situation. Professional expertise and self-confidence are important prerequisites and bring authordesign somewhat into a line with artistic activity [32]. External information – often in form of constraints for the design solution – and input from observations of different users may be included into the design processes as well, but the designer has a high amount of freedom and authority on problem framing and solution development.

We know and observed that people do not always follow a paradigm holistically (see also [33]), but also try to combine characteristics of different paradigms. Nevertheless, we observed that there is a

general connection between particular forms of information synthesis and a certain guiding design paradigm. Therefore, we believe it is helpful to begin analyzing the characteristics of information synthesis by telling between the different design paradigms involved. As a result of the preceding discussion, we distinguish between:

- the scientific/ rational design paradigm
- the human-centered design paradigm
- the authordesign paradigm

4.2 Perspectives on information synthesis

In this section, we explain the perspectives that we use to frame information synthesis in greater detail. The perspectives help us to deal with our research questions in higher resolution; they allow comparing differences between the forms of information synthesis in different design paradigms, and reveal new research questions for future information synthesis research.

The first perspective looks upon the state of the ***design problem / challenge*** being addressed in information synthesis. Here, we see in particular two important measures. First, we can distinguish between *well-definable and wicked problems*, that is between those which are ultimately definable (such as a mathematic problem) and those which are only provisionally describable (e.g. developing the perfect living concept) [30]. Second, we can distinguish between *particular and systemic design challenges*, thus those that look for a specific solution (mostly an object) that fits in a certain problem setting with rather few interdependencies (such as a kitchen object), and those that try to find an all-embracing solution for a systemic problem with manifold interdependencies (e.g. a corporate communication system) [34].

The second perspective looks upon the ***relevance of information synthesis for the entire design process***. As we found out in our field research, some interviewees did not know what the question was about when we were asking how they processed initially gained information. We realized that in some cases people assimilated information "on the fly" and most of the time on their own. In contrast, other interviewees stated that the synthesis was a very crucial point within the whole design process and its importance should not be underestimated, as it helps to identify general statements, principles, trends, needs and requirements with regards to the design task. In literature the importance of information synthesis for design processes also varies. Whereas some authors highlight information synthesis as an essential part of the design process [1,8], others do not even mention it as a distinct process phase [6].

The third perspective addresses the ***sequence and characteristics of subtasks*** involved in information synthesis. As our interviews show, people with a developed understanding of information synthesis generally discuss their research results with other people. It may be a colleague or a whole team, depending on company or school structure. During these conversations, people usually take notes, either on normal paper or sticky notes. Some participants summed it up under the term "storytelling". Afterwards, they try to find similarities of what they have heard and try to group them by general terms. Important topics are sometimes displayed in different frameworks or diagrams, such as a process diagram to show workflows or relationships. In the end, people write down their most important insights or principles. This relates to Kolko's methods of synthesis as e.g. "prioritizing" or "concept-mapping" [15] or the observations other researchers made [2,14,16]. Most of the subtasks have the intention of converging and structuring information, but sometimes iterations with diverging character for knowledge generation occur as well [35-37]. However, not everybody follows an elaborated structure when synthesizing information, but pursues a rather intuitive, coincidental sequence of steps.

The forth perspective focuses on ***decision making*** in information synthesis. This is an important issue as soon as it comes to situations in which designers have to prioritize or select between different pathways. Decision making, therefore, strongly influences agreements on statements, principles, trends, needs and requirements regarding the design task [8]. We realized from our interviews that the role of intuition for decision making in information synthesis has to be closer examined. When we asked our interview partners how they identify and define insights or decide on the priority of information, nobody could give a clear answer. In particular designers with a high level of experience said they follow their intuition, whereas interviewees with not so much experience stated that decision making was very challenging because they did not develop enough intuition yet. This finding is also supported by literature, suggesting that the reliability of intuition in design processes is dependent on experience [1,15,38,39].

The fifth perspective addresses the ***extent of discursivity*** in information synthesis. Our interviews suggest that discourse between the members of a design team is seen as a decisive part of information synthesis. Some interviewees even defined the synthesis as "a team process with a lot of discussions". On the contrary, other interviewees stated that they collect and synthesize information in general on their own and talked about their observations only with a few people, generally expert designers, later on. Thus, we could observe that the extent of discursivity varies with teams and design situations. In literature, discourse among design teams is seen as rather important within the frame of the human-centered design paradigm [9,40].

The sixth perspective looks upon the different forms of ***re-representation of information*** involved in design processes [41]. Here we ask what information (based on what kind of knowledge [20]) is represented in the information synthesis as well as what kind of media is used for re-representation. Our interview partners use different kinds of media to communicate and process information, though analog media such as paper, sticky notes and traditional whiteboards are the most commonly used. Nevertheless, especially interviewees who are working in companies (instead of education) stated that at some point digital media in form of word processors, presentation programs or wikis are used as well. The amount of externalization of information also varies. Some people reported that is very important to document as much as possible, others rarely use any kind of documentation and synthesize insights directly into concept prototypes.

Converging information and finding design principles with a higher degree of abstraction is one of the goals of the synthesis phase. However, we observed different levels of ***information trade-off*** among our interview partners, which constitutes our seventh perspective. Some interviewees try to keep and externalize as much information as possible, partly because they are afraid to lose information and partly because their stakeholders have set some unavoidable restrictions. Others stated that it is not possible and also not desirable to keep all information in the design process, as it is important to quickly focus on the most important points. Most interviewees agreed that it depends on the level of experience to decide which and how much information is important to include in the design process.

The eighth perspective focuses on ***team interaction***. Throughout the interviews, we noticed several incidences in which implicit team dynamics influence the synthesis process on a rather unconscious level. For instance, interviewees mutually agreed that only if team members share a common ground of trust and respect, the basis for joint decisions would be given. In another example, an interviewee stated that persons enforcing the own view strongly influence the whole synthesis process. Also, the information synthesis is described as exhausting and its success highly depends on the motivation of the team members. Therefore, we regard the area of team interaction with a special focus on team dynamics, biases and motivation as important for a deeper understanding of information synthesis.

The ninth perspective addresses to what extent it is required to communicate preliminary results to external persons. Interviewees who are working in companies stated that customers and stakeholders complain that they hardly see what happens during the synthesis phase – a problem that is also addressed in literature [1]. Several clients want to understand where the design ideas and solutions originate from and whether the budget for e.g. user research has been spent reasonably. However, such requirements generally presume seeing the relationship between design solutions and user research data, which is normally only possible towards the end of the design process. In particular in early stages of the design process, designers often face communicability gaps that make it difficult to tell outsiders about the design process's progress. In this context, information synthesis can help to create presentable states of knowledge. However, our interviews suggest that this seems to be less of a problem for the more experienced designers, as the relationships between clients and designers then rather build upon trust. This shows that ***external communicability requirements*** depend on the relationship between designers and clients and how much they confide in the respective design approach.

Our last perspective focuses on the ***organizational restrictions and enablers*** that affect the information synthesis. Organizational restriction that we could observe were, for instance, rather tight time frames for information synthesis in general and – especially when people work on several projects at the same time – disruptive work flows that do not allow concentrated team work. Teams also face problems when one or more team members are missing and have to be updated afterwards. Such insights show that organizational patterns can clearly influence the information synthesis itself, so that research in this field should also focus on its organizational preconditions and enablers.

Table 1: Perspectives on information synthesis

Perspectives	**Description**
Design challenge / problem	Is the design challenge rather systemic or particular, is the problem structured or fuzzy ("wicked")?
Relevance of information synthesis for the entire design process	What role does the information synthesis play for the entire design process?
Sequence and characteristics of subtasks	What kinds of subtasks are used? Do they rather have a converging or diverging character? How do both forms of subtasks interact?
Decision Making	How do people come to a decision? How much is it influenced by intuition and experience? How can people make a decision if they do not have sufficient experience?
Extend of discursivity	To what extend is discourse between different people decisive for the convergence of information and the generation of insights? By what means is discourse supported?
Re-representation of information	What kind of information is represented? What kinds of media are used to communicate and process information? To what extend is the synthesis influenced by verbal communication, to what extend by externalized artifacts?
Information trade-off	Is there any loss of information during the process? Why? Is it a conscious or unconscious act?
Team interaction	How much is the synthesis influenced by team composition and team dynamics (personalities, motivation, etc)?
External communicability requirements	To what extend should the process and the results of the synthesis be communicable to stakeholders (such as clients and superiors)? What forms of communication are used?
Organizational restrictions and enablers	Which organizational prerequisites hinder the information synthesis? Which foster and support the work?

4.3 A framework of hypotheses for information synthesis research

Based on the design paradigms and perspectives developed above, we suggest in this section a framework for information synthesis research. For every perspective we suggest hypotheses with regards to the different design paradigms. All hypotheses are derived from our research data. The aim of the framework is a) to offer a comprehensive overview on the various aspects and notions involved in information synthesis research, b) to suggest detailed hypotheses, which allow both orientation within this research field's complexity and stimulation for further studies, and c) to propose a flexible framework structure that can be easily expanded, adapted or restructured.

Table 2: Hypotheses on information synthesis according to different design paradigms

Perspectives	**Design paradigms**		
	Scientific	**Human-centered**	**Authordesign**
Design problem/ challenge	Definable / systemic	Wicked / particular	Wicked / particular
Relevance of information synthesis for the entire design process	Important: Information synthesis at the beginning of the design process; employed to frame the design problem	Very important: Decisive phase to integrate user research data into the design process and to process the information for further creative usage	Rather unimportant: Information mainly consists of external design constraints; within these constraints, designers form the design process and its outcome rather subjectively

Perspectives	Design paradigms		
	Scientific	**Human-centered**	**Authordesign**
Sequence and characteristics of subtasks	Predominantly converging; diverging subtasks only for supplementary information retrieval	Against the background of a wicked problem setting: alternation between converging (information structuring) and diverging (knowledge generation and revision) subtasks	Predominantly converging, due to low relevance of synthesis in general and reliance on external constraints
Decision Making	Rational decision making throughout; decisions based on well-defined problem documentation; transparent and comprehensible evaluation and prioritization of alternatives	Decisions based in particular on user information, including high amount of tacit information; high importance of perspective-taking and the development of empathy for decision making; intuition can play a decisive role	Decisions based on a high level of intuition generated through design experience; rather autonomous decision making
Extend of discursivity	Rather unimportant due to a high degree of certainty of information and knowledge	Very important due to a high degree of ambiguous information and knowledge; discursivity as a means for exchanging implicit and empathic knowledge	Little necessity for discursive (and diverging) synthesis due to the low relevance of synthesis in general and reliance on external constraints; focus on quick convergence
Re-representation of information	Representation of explicit information; highly documentation-driven; rather few iterations	Representation of explicit and implicit user information (including emphatic knowledge); diverse and intense media usage; many iterations	Representation of external constraints; little media usage, rather few iterations
Information trade-off	Ideally no trade-off; all information are included in the problem framing and should be represented in the solution	Trade-off unavoidable due to diverse user input and ambiguous information; during synthesis the team consciously and unconsciously decides which information should be kept and where it is possible to generalize to an abstract level	Trade-off not significant due to its low relevance; the author consciously decides how to deal with constraints and what information to include
Team interaction	Synthesis is rather not influenced by team dynamics and composition due to explicit and definite	Synthesis is very much influenced by team dynamics as every member introduces user research data and	Synthesis is rather individually-driven, thus there barely is team interaction.

Perspectives	Design paradigms		
	Scientific	**Human-centered**	**Authordesign**
	character of information	an own point of view. Motivation and results depend on good team interaction	
External communicability requirements	It is generally expected to document every design step of the design process in order to make the whole process in detail comprehensible for stakeholder	Communicability is required to generate trust between designers and stakeholders (esp. clients) with regard to the design process quality. Communicability can be obstructed due to the ambiguity of information; appropriate media vary	Low external communicability requirements; stakeholders confide in author's competence and judgment
Organizational restrictions and enablers	Fits well to "traditional" milestone-based project planning techniques and documentation requirements	Organization should be able to absorb discontinuity and unexpected events, otherwise organization restrictions might hinder the project quality	Only few interdependencies with organizational patterns, therefore few organizational restrictions or enablers

5 CONCLUSION AND OUTLOOK

The purpose of this paper is to "open the black box" of information synthesis and to display its characteristics within design processes in detail. We presented a framework showing how different perspectives of synthesis lead to different insights depending on the chosen design paradigm. We stated these insights in form of hypotheses, derived from expert interviews and literature review. In further research efforts, these hypotheses and their implications should be verified and further explored.

Interesting to us is further research on the intersections between the different design paradigms and the consequences they have on information synthesis. In particular, we ask ourselves how the choice of the design paradigm is determined a) by the given design challenge and b) the experience of the design team. We wonder if experienced designers tend to prefer an *authordesign* paradigm, as they are able to draw on high-level experience and thus on a high level of reliable intuition. As a consequence, information synthesis would lose its importance the more experienced the designers are. However, the *human-centered* paradigm gives more direction and orientation throughout the design process, while information synthesis is of high importance as it decides in what quality external knowledge can influence the design process. Consequently, the designer's role would change from a design expert to a "design midwife" who should be able to deal with highly diverse and complex amount of information.

Against this background, another research question arises, that is how activities of information synthesis can be supported with particular tools. Those tools might not only increase the quality of information synthesis, they may also help to improve external communicability, decision-making and dealing with information trade-off. Concluding, the field of information synthesis offers diverse research possibilities for different areas of interest. We hope that this contribution encourages further researchers to become engaged within this field of research.

REFERENCES

[1] J. Kolko, "Abductive Thinking and Sensemaking: The Drivers of Design Synthesis," *Design Issues*, vol. 26, 2010, pp. 15-28.

[2] A.C. Robinson, "Collaborative synthesis of visual analytic results," *2008 IEEE Symposium on Visual Analytics Science and Technology*, IEEE, 2008, pp. 67-74.

[3] U. Brandes, M. Erlhoff, and N. Schemmann, *Designtheorie und Designforschung: Design studieren*, UTB, 2009.

[4] M. Baxter, *Product design: practical methods for the systematic development of new products*, Stanley Thornes, UK, 1999.

[5] J.C. Jones, *Design Methods*, John Wiley & Sons, New York, 1992.

[6] B. Lawson, *How designers think: the design process demystified*, Elsevier, 2006.

[7] T. Lindberg, R. Gumienny, B. Jobst, and C. Meinel, "Is there a need for a Design thinking Process?," *Design Thinking Research Symposium DTRS8*, 2010, pp. 243-254.

[8] J. Hey, J. Yu, and A.M. Agogino, "Design Team Framing: Paths and Principles," *International Conference on Design Theory and Methodology*, 2008, pp. 1-12.

[9] K. Krippendorff, *The Semantic Turn: A New Foundation for Design*, CRC Press, 2006.

[10] C. Alexander, *Notes on the synthesis of form*, Harvard University Press, 1964.

[11] G. Bamford, "From analysis/synthesis to conjecture/analysis: a review of Karl Popper's influence on design methodology in architecture," *Design Studies*, vol. 23, May. 2002, pp. 245-261.

[12] H. Plattner, C. Meinel, and U. Weinberg, *Design Thinking*, mi-Wirtschaftsbuch, 2009.

[13] D. Schön, "Problems, frames and perspectives on designing," *Design Studies*, vol. 5, Jul. 1984, pp. 132-136.

[14] P. Pirolli and S. Card, "The sensemaking process and leverage points for analyst technology as identified through cognitive task analysis," *Proceedings of International Conference on Intelligence Analysis*, 2005.

[15] J. Kolko, *Exposing the Magic of Design: A Practitioner's Guide to the Methods and Theory of Synthesis (Human Technology Interaction Series)*, Oxford University Press, USA, 2011.

[16] P. Isenberg, A. Tang, and S. Carpendale, "An exploratory study of visual information analysis," *CHI '08: Proceedings of the SIGCHI conference on Human Factors in computing systems*, 2008, pp. 1217-1226.

[17] C. Naumer, K. Fisher, and B. Dervin, "Sense-Making: a methodological perspective," *CHI2008 Workshop on Sense-Making, Florence*, 2008, pp. 1-5.

[18] W. Wright, D. Schroh, P. Proulx, A. Skaburskis, and B. Cort, "The Sandbox for analysis: concepts and methods," *CHI '06: Proceedings of the SIGCHI conference on Human Factors in computing systems*, 2006, pp. 801-810.

[19] J.E. Introne, "Supporting group decisions by mediating deliberation to improve information pooling," *GROUP '09: Conference on Supporting Group Work*, 2009, pp. 189-198.

[20] A. Heylighen, J.E. Bouwenb, and H. Neuckermans, "Walking on a thin line - Between passive knowledge and active knowing of components and concepts in architectural design," *Design Studies*, vol. 20, Mar. 1999, pp. 211-235.

[21] A. Dong, "The latent semantic approach to studying design team communication," *Design Studies*, vol. 26, Sep. 2005, pp. 445-461.

[22] S. Gasson, "The Dynamics of Sensemaking, Knowledge, and Expertise in Collaborative, Boundary-Spanning Design," *Journal of Computer-Mediated Communication*, vol. 10, 2005.

[23] J. Stempfle and P. Badke-Schaub, "Thinking in design teams - an analysis of team communication," *Design studies*, vol. 23, 2002, p. 473–496.

[24] N. Cross, "The nature and nurture of design ability," *Design Studies*, vol. 11, 1990, pp. 127-140.

[25] W. Muller, "Typology and the organization of design knowledge," *Design Studies*, vol. 17, Apr. 1996, pp. 111-130.

[26] B.G. Glaser and A.L. Strauss, *The Discovery of Grounded Theory. Strategies for Qualitative Research*, 1967.

[27] K. Dorst and J. Dijkhuis, "Comparing paradigms for describing design activity," *Design Studies*, vol. 16, Apr. 1995, pp. 261-274.

[28] N. Cross, "From a Design Science to a Design Discipline: Understanding Designerly Ways of Knowing and Thinking ," *Design Research Now*, R. Michel, ed., Basel: Birkhäuser Basel, 2007, pp. 41-54.

[29] D.A. Schön, *The Reflective Practitioner: How Professionals Think In Action*, Basic Books, 1983.
[30] H. Rittel, "On the planning crisis: systems analysis of the first and second generations," *Bedriftsokonomen*, vol. 8, 1972, p. 390–396.
[31] R. Buchanan, "Wicked Problems in Design Thinking," *Design Issues*, vol. 8, 1992, pp. 5-21.
[32] B. Schneider, *Design — Eine Einführung*, Basel: Birkhäuser-Verlag, 2005.
[33] W. Visser, "Designing as Construction of Representations: A Dynamic Viewpoint in Cognitive Design Research," *Human-Computer Interaction*, vol. 21, Mar. 2006, pp. 103-152.
[34] J. Gharajedaghi, *Systems Thinking: Managing Chaos and Complexity: A Platform for Designing Business Architecture*, Amsterdam: Elsevier, 2006.
[35] J.P. Guiltford, *The Nature of Human Intelligence*, McGraw-Hill, New York, 1969.
[36] C.L. Dym, A.M. Agogino, Ö. Eris, D.D. Frey, and L.J. Leifer, "Engineering design thinking, teaching, and learning," *Journal of Engineering Education*, vol. January, Jan. 2005, pp. 103-120.
[37] D. Rhea, "Bringing Clarity to the 'Fuzzy Front End'," *Design research: methods and perspectives*, B. Laurel, ed., The MIT Press, Cambridge, Massachusetts, 2003, p. 334.
[38] A. Cropley, "In praise of convergent thinking," *Creativity Research Journal*, vol. 18, 2006, p. 391–404.
[39] H. Beyer and K. Holtzblatt, *Contextual Design: A Customer-Centered Approach to Systems Design*, Morgan Kaufmann, 1997.
[40] P. Lloyd, "Storytelling and the development of discourse in the engineering design process," *Design Studies*, vol. 21, Jul. 2000, pp. 357-373.
[41] J.A. Edelman, L. Leifer, B. Banerjee, N. Sonalkar, M. Jung, and M. Lande, "Hidden in plain sight: Affordances of Shared Models in Team Based Design," *ICED '09: International Conference on Engineering Design*, Stanford: 2009, pp. 2-395-406.

Contact: Raja Gumienny
Hasso Plattner Institute
Department of Internet Technologies and Systems
Prof.-Dr.-Helmert-Str. 2-3
14482, Potsdam
Germany
+49 331 5509 534
+49 331 5509 325
raja.gumienny@hpi.uni-potsdam.de
http://www.hpi.uni-potsdam.de/teleboard.html

Raja is a PhD candidate in the HPI-Stanford Design Thinking Research Program. Within the project "Tele-Board" she researches how digital tools can improve the collaboration of geographically distributed design thinking teams. In particular, her research focuses on special support for the information synthesis.

Tilmann is a PhD candidate in the HPI-Stanford Design Thinking Research Program and the chair of organization and human resources at the University of Potsdam. His research focuses on the potentials and implementation of design-led product development in large-scale organizations. He has conducted case study research on the implementation of design thinking in the IT industry.

Christoph is CEO of the Hasso Plattner Institute and a professor at the department of Internet Technologies and Systems. His research focuses on Future Internet Technologies and on innovative Internet Applications, mainly in the areas Web-university, e-Learning and Telemedicine. He is also a program director of the HPI – Stanford Design Thinking Research Program.