TRANSDISCIPLINARY DESIGNER-SCIENTIST COLLABORATION IN CHILD ONCOLOGY

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ABSTRACT

Integrating knowledge and expertise from designers and scientists proposes solutions to complex problems in a flexible and open-minded way. However, little insight is available in how this collaboration works. Therefore, we reflected on a research project aimed at supportive care interventions for child oncology, and detected barriers and enablers for effective designer-scientist collaboration. We interviewed medical scientists (n=2), designers (n=5), health care professionals (n=2), design students (n=3), and one design innovation-expert. Enablers appeared a receptive attitude towards innovation, and shared terminology facilitated by participatory design tools, internal communication means, and common goals. Largest barrier was unstable team membership. Future collaborative research projects might benefit when preventing barriers and stimulating enablers.

INTRODUCTION

Although much is known about the relationship between design and science on the one hand (Rust 2007), and collaboration between designers and other disciplines on the other (Derry, Schunn & Gernsbacher 2005), little research is available focusing on collaboration between designers and scientists in research projects (Peralta & Moultrie 2010). However, existing research concludes that designers can make a substantial impact to research projects, if involved early in the process. It is suggested that integrating knowledge and expertise from designers and scientists proposes solutions to complex problems in a flexible and open-minded way (D'Amour et al. 2005). Well-known collaborative projects are SymbioticA (a research laboratory enabling artists and researchers to engage in biology practices) (Catts & Bunt 2004) and Material Belief (a network in which designers, engineers, scientists, and social scientists explored potential implications of emerging biomedical and cybernetic technologies) (Beaver et al. 2009). This positive impact underlines the importance of investigating the cause, so joint projects can benefit from the insights (Peralta & Moultrie 2010). In this paper, a research project aimed at creating supporting care interventions for pediatric oncology patients served as a case to understand the nature of collaboration between scientists and designers, using concepts from interdisciplinarity as a model for analysis (see Literature and Theory-section). Based on the results, theoretical and practical implications are provided from which projects where designers and scientists collaborate might benefit.

LITERATURE AND THEORY

In literature, no consensus exists regarding the definitions of "science" and "design" as disciplines.

Some authors claim design to be science, others do not. We do not mingle ourselves in this fundamental discussion, but previous research provides ample evidence that designers' and scientists' professional characteristics are more different than similar. According to Peralta and Moultrie (2010), most important differences are that (1) designers generate new experiences and scientists new knowledge, (2) designers explore the unobservable and inexistent and scientists the observable and existent, (3) designers seek plausibility and scientists truth, (4) designers produce course of actions and scientists generalizations and theory, and (5) designers prefer images whereas scientists refer abstract mathematical explanations. Although full of contrast, it seems interesting to focus on how designers' and scientists' competences complement each other in a joint project. That synergy is likely to occur, might be caused by the similarities in activities scientists and designers deploy: (1) Cycles are equal in number and comparable (observation versus analysis, induction versus synthesis, deduction versus simulation, testing versus evaluation, and evaluation versus decision), (2) they both proceed experimentally, and (3) make use of scientific knowledge. It is likely that design and science might benefit from each other when integrated. To our knowledge however, there are only few papers available focusing on designer-scientist collaboration in research projects (Peralta & Moultrie 2010; Rust 2004; Rust 2007). Based on multiple cases, Rust found that designers may have a meaningful role in scientific research by (1) unlocking tacit knowledge because designers act as provocateurs, (2) helping to disseminate scientific knowledge among non-scientists, (3) facilitating the advancement of scientific research, by providing means of experimentation and reflection, and (4) challenging scientists' perceptions and encouraging the pursuit of new research directions since designers appear to be pragmatic and instrumental, and therefore scientists are sometimes forced to change their behavior and reveal new possibilities.

Even though Rust offers an interesting perspective on interdisciplinary collaboration, he does not present evidence to sustain his claims. Also, he only took into account the designers' perspective. Results would have been more comprehensive when scientists were involved in the reflection. Therefore, we chose to reflect on a research project in which designers collaborated with social, medical, and engineering scientists, both considering the views from scientists and designers. Due to the lack of studies focusing at collaboration between designers and scientists, no theoretical framework was available for analysis. Therefore, concepts were derived from literature in interdisciplinary collaboration, as suggested by Peralta & Moultrie 2010; Peralta, Driver & Moultrie, 2010). We used insights from interdisciplinary projects to characterize our joint research project and identify facilitators and barriers in design and science

collaboration (Klein 2005; Epstein 2006; Reich & Reich 2006). Identifying barriers might also generate possible ways to overcome them and detecting facilitators might contribute to the small knowledge base regarding advantages of design-science collaboration.

CLASSIFICATIONS OF INTERDISCIPLINARY COLLABORATION
A large variety of models exist to classify interdisciplinary collaboration. Some of them emphasize orientation, structure, constraints of joint projects (Klein 2005), others stress interaction levels or patterns of collaboration varying from distributed to integrative (Epstein 2005). According to Peralta and Moultrie (2010), a comprehensive level of comparison is lacking. Therefore, they propose a model with four levels of research engagement for designers in collaborative projects:
1. Designers act as "design suppliers". Design tasks are not directly related to the research questions. Designers have no research membership;
2. Designers are "research group members". Design tasks not directly related to research questions;
3. Designers' activity directly related to the research questions but the research agenda is set and leaded by the scientists. Disciplinary roles are kept;
4. Designers and researchers team up to define research questions and find the answers. Disciplinary roles are blurred and activities defined by research questions.

This distinction is comparable to the frequent used qualifiers of "multidisciplinary", "interdisciplinary", and "transdisciplinary" that are often used interchangeably and are rarely clearly defined. According to a review of D'Amour et al (2005) on interprofessional collaboration, these qualifiers can be defined as follows: (1) Multidisciplinary: different professionals work on the same project but independently or in parallel. Interaction is on a limited and impermanent basis. (2) Interdisciplinary: different professionals work on the same project and integrate knowledge and expertise. Interaction aims at common decision-making and there is a common space and shared ownership. (3) Transdisciplinary: deliberate exchange of knowledge, skills, and expertise that transcend traditional discipline boundaries.

Combining Peralta's and D'Amour's categories generates the following classification for science-design collaboration:
• Multidisciplinary: Designers as "design suppliers" and research group members;
• Interdisciplinary: Designers' activity related to research questions;
• Transdisciplinary: Designers and researchers team up.
This classification enabled us to specifically describe the collaboration in our project (see Results-section).

BARRIERS OF DESIGN-SCIENCE COLLABORATION

Klein et al. (2005), Reich and Reich (2006), and Rust (2004 2007) mentioned all type of barriers for successful collaboration in interdisciplinary projects, varying from characteristics from individual team members to organizational issues such as restrictive legal mandates. In order to facilitate analysis, we categorized these factors into a new model, consisting of micro (individual), meso (interpersonal), and macro (organizational) levels (Verhoeven 2009), listed in Table 1.

Level	Barriers
Micro (individual)	- Lack of integrative skills and systems thinking (Klein) - Social and psychological impediments (resistance to innovation) (Klein)
Meso (inter-person al)	- Conflict over technical issues (research methodology, problem definition, scheduling) - Disciplinary ethnocentrism (Klein)/ silencing "lower status" disciplines (Reich) - Leadership style (Klein) - Miscommunication: lack of common specialized language (Rust 2007) - Tokenism: disciplines represented in team but not included in decision making processes (Reich) - Unstable membership (Klein) - Unwillingness to take risks (Klein)
Macro (organizational)	- Lack of incentives/ reward system (Klein) - Restrictive legal mandates (Klein) - Time and budget constraints (Klein)

Table 1. Barriers of interdisciplinary collaboration between scientists and designers

The aforementioned model will be used to analyse the case study presented below.

ENABLERS OF DESIGN-SCIENCE COLLABORATION

Also, determinants of fruitful collaboration between designers are described in literature (Epstein 2005). The same categorization is used to describe these (see Table 2).

Level	Enablers
Micro (individual)	-Attitude (receptive, open-minded, proactive in learning from other disciplines - Sense of humour
Meso (inter-person al)	- Communication: fundamental shared terminology should be established - Facilitator to ease communication - Allocation of responsibilities - Leader who defines common problem and language
Macro (organi zationa l)	- Time (interdisciplinary collaboration demands more time) - Budget (interdisciplinary collaboration requires more budget) - Physical proximity: Face-to-face contact is fundamental - Institutional support

Table 2. Enablers of interdisciplinary collaboration between scientists and designers

As can be seen in Tables 1 and 2, barriers and enablers relate to the similar issues. Enablers mentioned in Table 2 are framed oppositely in Table 1, which is obvious. For instance, at micro level: a resistive attitude towards innovation opposes a receptive, open-minded attitude. The model presented in Tables 1 and 2 will be used to analyse the joint project to develop supportive care interventions in child oncology, which is extensively described in the next section.

DATA AND METHODS

First, the collaborative design-science project that served as a case will be described. Second, we will elaborate on how we gathered, saved, and analysed our data to reflect on the collaboration.

CASE DESCRIPTION

Cancer is the main cause of death among Dutch children. Adequate exercise, eating and drinking increases their chance of survival, but for many seriously ill children this is difficult, since they are too exhausted to eat and exercise. Most of the existing research in oncology focuses on methods of treatment such as chemotherapy and radiotherapy. So far, no research and/ or design projects focusing on supportive cancer care for children, such as exercise and nutrition have been reported (Brinksma et al. 2014).

To fill both this practical and theoretical gap, designers and scientists with various backgrounds joined their forces in the POKO-project. POKO is the Dutch acronym of "Particatief Ontwerpen voor KinderOncologie", meaning "Participatory Design for Child Oncology". In this project, designers and scientists together conducted research in order to design interventions that facilitate adequate physical and eating behavior among children suffering from cancer. The project was carried for and with the Children's Oncology department of the University Medical Center

Groningen (UMCG). UMCG has 1300 beds, 40000 yearly admissions, and 10000 employees. POKO was a one-year research project (September 1st, 2013-June 30th, 2014), partially funded by a grant stimulating collaboration between creative industry, science, and education. Total budget was 100.000 euros. The project was managed by the Co-design research group at Utrecht University of Applied Sciences. The project brought together the network depicted in Figure 1.
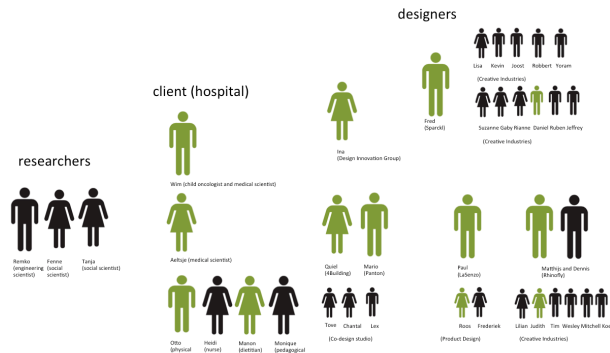

Figure 1. Network of the POKO-project. Green icons represent participants in the reflective interviews.

Although icons and fonts in Figure 1 are hardly readable, they depict the size of the network. The network consisted of:
• Five scientists (two medical researchers from the Child Oncology Department of UMCG and three researchers from Utrecht University of Applied Sciences, having a
background in engineering and two in social sciences);
• Five designers from different design agencies, each specialized in another phase of the design process: 4Building and Panton's expertise involves mapping the stakeholder needs in a care setting and translating these into requirements. LaSenzo and Sparckl are specialized in the actual design for care, whereas Rhinofly is experienced in rapid prototyping and testing;
• Twenty-two design students who either individually or in a group actually created the interventions, each under supervision of one of the five professionals designers who actually created the interventions;
• Four health care professionals from the Child Oncology Department of University Medical Centre Groningen;
• One design innovation expert from an independent organization.

Project duration was split up in two parts. During the first five months, designers together with researchers *explored* the problem and *conceptualized* directions of solution. During the second part, four concepts were *prototyped* into an intervention and were *evaluated*. The design process is depicted in Figure 2. Now, the participatory design process will be described into more detail.
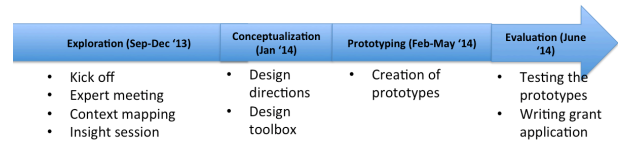

Figure 2. Overview of participatory design process

Exploration (September-December 2013): The project kicked off at September 3rd, 2014 with a joint face-to-face meeting involving all scientists and designers. Using expectation mapping, common goals and objectives were set and a global planning and task distribution was made. It was decided that given their expertise, designers from Sparckl, Panton, and 4 Building would map the context of eating and exercising among children with cancer. Therefore, they conducted an "expert meeting" on October 10th, during which the health care workers from the Child Oncology Department could express their tacit knowledge and feelings regarding the topic. The physical therapist, dietician, oncologist, nurse, nutrition assistant, and pedagogical support attended, next to all designers and researchers. Important insights were revealed, such as "Parents are happy when their child eats something, even if it is unhealthy." and "Largest challenge are teenagers, who are used to lay down all day long, using their smart phone and are not intrinsically motivated to move, as toddlers are." These insights were used to detect topics that had to be elaborated on in the context mapping research, conducted on October 17th, during which the three designers interviewed six children suffering from cancer in the hospital. Research material consisted of a timeline that children could fill in together with the designer and their research by means of drawing and stickers with emoticons (see Figure 3). Emotions and ideas regarding nutrition and exercise during the treatment of cancer became clear. Based on the results of the expert meeting and context mapping, six personas were created that served as inspiration during the entire design process. Then, on November 26th, an "insight session" was organized, attended by all involved health care professionals, researchers, and designers (also the designers who had not been actively involved yet, but would be in the next phase). During the sessions, the medical researchers presented the problem from a medical point of view and then, the designers shared their findings from the expert meeting and context mapping. This served as input for a "design exploration" on the ward. In teams consisting of one health care professional, one researcher, and one designer, design opportunities were detected at the actual ward among the patients. Then, possible solutions were shared and related to insights from previous research. Finally, all problems and solution directions were consolidated into four "design directions", two relating to nutrition and two to exercise, as is showed in Table 3.

Figure 3. Fragment of raw material generated by context mapping among children with cancer and their parents.

	Physical product	Interactive media product
Nutrition	Taste lab: mobile setup where children can discover (new) flavors that fit their preference at that moment in treatment process.	Insight kit: providing parents and children with cancer insight in the various phases of treatment and possible actions to undertake to stimulate adequate eating behavior.
Exercise	Discover worlds: interventions in the hospital setting aimed at stimulating activity at unexpected places and moments.	Exercise kit: to enable parents and their children with cancer think about creative ideas themselves in order to keep the child active.

Table 3. Design directions resulting from exploration phase

Conceptualization (January 2014): An important shift occurred during this phase. In order to enable the (student) designers to prototype successful interventions, it was of vital importance to equip them with the contextual insights we captured during the exploration phase. Since the problem is complex and hard to understand, three students –supervised by a professional designer- created a "design toolbox" consisting of the six personas, and three exercises during which designers had to express their own experience and expectation towards nutrition and exercise during cancer and to draw some first solution ideas. Simultaneously, the researchers and designers together formulated four design assignments for students and recruited students from several backgrounds (product design and engineering, multimedia design, et cetera).

Prototyping (February-May 2014): Twenty-two students entered the project. They all kicked of by using the design toolkit and visiting the oncology ward. Rhinofly, LaSenzo, and Sparckl coached the students during their design process. Objective was that each student group delivered a working prototype of their chosen solution direction. Each (group of)student(s) applied participatory design methods and continuously checked with the medical researchers and health care professionals whether or not their ideas matched daily clinical practice. Some of the applied methods were: desk research of existing interventions, observation of "healthy" children playing in the play garden or in a science museum, visiting lectures on the topic, interviewing a design innovation consultant, et cetera. Eventually, the students generated four

Prototypes, listed in Table 4.

	Physical product	Interactive media product
Nutrition	Taste lab: part of the car with which breakfast and lunch are served at the hospital, including a "taste experience" facilitated by the nutrition assistant.	Parent Toolkit "Reis van 5" " aimed at discovering new flavors of the child because the taste changes by chemotherapy.
Exercise	Blox. :blocks with which children can transform their hospital bed into something else (e.g., a hut) to stimulate activity.	Movement kit: clock and cards facilitating physical activity.

Table 4. Prototypes resulting from prototyping phase

Evaluation (June 2014): Eventually, all four concepts were evaluated with health care professionals, and children with their parents. On June 19th, a joint evaluation session (duration of two hours) with all designers and all researchers was undertaken. Each intervention was presented by the involved designer and evaluated according to a set of criteria: feasibility, long term-effect, low production costs, et cetera. Then, since the project was very successful, researchers and designers together wrote a grant application to elaborate on the interventions and evaluate them in clinical practice. In September 2014, we heard the request was honored and received 450.000 euros to perform two more years of joint research.

CASE REFLECTION DATA AND METHODS
In order to reflect on barriers and enablers of the designer-researcher collaboration, 13 semi-structured interviews among the medical scientists (n=2), designers (n=5), involved health care professionals (n=2), design students (n=3), and one design innovation-expert were conducted by one of the participating social scientists (this paper's first author). The respondents all were engaged in the project and are displayed in green in Figure 1. The interview was semi-structured and occurred based on a visual project time line (similar to Figure 2) depicting all research and design activities. The researcher started with the question: "Reflecting on the project, what is the first thing to recall?" Then, when respondents were finished, the researcher together with the respondent discussed all research and design activities on the time line and while doing so, detected critical incidents regarding multidisciplinary collaboration. Interviews were conducted between May 23rd and June 18th, 2014. Nine interviews took place face-to-face and three through Skype. Interviews were not recorded, but extensive note taking took place by the researcher.

Data analysis was based on coding. The coding scheme consisted of Table 1 and 2 (see Literature and theory-section).

RESULTS

CHARACTERISTICS OF INTERDISCIPLINARY COLLABORATION

According to Peralta et al.'s (2010) and D'Amour et al.'s (2005) classification, the POKO-project could be qualified as "transdisciplinary": Designers and researchers were equally engaged in the project and together defined and conducted research activities. E.g., researchers took part in sessions initiated by the designers (expert session, insight session), designers performed interviews with children and their parents building on results of medical research (context mapping), and researchers and designers jointly analysed retrieved data (insight session, evaluation session). During the kick-off meeting, designers and researchers really teamed up to define common research questions, and particularly during sessions, disciplinary roles blurred. Throughout the entire project, these common goals were repeated and if needed, reformulated.

BARRIERS

Analysis showed barriers mentioned by the respondents predominantly referred to "lack of integrative skills and systems thinking" at the micro-level, and "unstable membership" at the meso-level.

Regarding the micro-level: During the second project part, particularly in the Prototyping-phase (February-May 2014), the design process was heavily impeded by design students who worked in teams, but who were not yet very experienced in working multi-disciplinary. Rather than complementing, the integration of disciplines worked counter-productive: *"There were many disciplines in our group. Two designers (me and another boy), media technologists, but also economists, but we all wanted different things. The other designer did not cooperate whereas I wanted to join forces. The media technologists thought in a very technical way and immediately wanted to start creating something, whereas we as a designers wanted to investigate the problem more."* (Design student, June 16th, 2014). And: *"Collaboration among students and student groups should have been mandatory, because now it was unprofessional. There even was a hate relationship among different teams. Students whined a lot, about each other, about workload, et cetera."* (Designer [anonymously], June 12th, 2014).

At the meso-level, unstable membership was the most prevailing barrier, both among students as well as designers. As mentioned in the Data and methods-section, students and professional designers were allocated to project phases according to their expertise. However, this resulted in designer(-student)s not being involved throughout the entire project. Although we tried to anticipate to this by using a design toolbox and later on in the project, a news letter, it appeared harder to keep design(student)s committed to the project when they were not involved from the early start and during the entire year: *"The designers that were not active during a particular phase did not know what was going on. A community should be kept alive. Also, the students did not always keep the designers and scientists posted, and becoming up-to-date each time took a lot of effort for me as a designer."* (Designer LaSenzo, May 27th, 2014).

When looking at the identified barriers rom literature (see Table 1), most of them were not mentioned during the interviews. There was no resistance towards innovation (micro), no conflict over technical issues, no disciplinary ethnocentrism or tokenism, or unwillingness to take risks (meso), neither there was a lack of incentives, restrictive legal mandates nor time and budget constraints (macro). Moreover, barriers particularly seem to play a role among students. Among the professional designers, only unstable membership played a role as a barrier.

ENABLERS

At the microlevel, multiple respondents (indirectly) indicated to be open-minded, which contributed to the project's success. E.g., *"This way of working is very inspiring, very refreshing, very nice to be part of. We started blank rather than from a hypothesis as we are used to in medical research. I definitely take this with me in my future career as an oncologist."* (Child oncologist, June 18th, 2014). And *"I never thought of the possibility to learn from Post-it's and thinking out of the box, very fascinating!" (Medical researcher, June 18th. 2014).* Medical researchers were proactive in applying and learning from the creative research tools deployed by the designers, whereas designers read the scholarly publications written by the medical researchers. Also, there was personal empathy between researchers and designers, caused by similarities in character (positivism, enthusiasm, humour). Joint sessions were always characterized by a lot of laughter.

The majority of enablers were present at the meso-level. Fundamental shared terminology appeared crucial. This was reached through 1. Participatory-design approach 2. Internal communication means, and 3. Common goals. First, the participatory design approach not only served the design quality of the interventions itself, but also shared understanding among designers and scientists. For instance, based on the expert meeting and context mapping in the Exploration-phase, it appeared impracticable to divide children with cancer into any category: age, hobbies, phase of treatment, type of cancer; each patient appeared to literally have its own disease. Then, one of the student designers who interviewed various physical therapists and pedagocial staff came up with the "Energymeter", representing the only thing all children with cancer have in common: The degree with which they are able to move, varying from lying in bed all day long (Phase 0) to sitting up in bed (Phase 1) and walking through the entire hospital (Phase 6). This categorization appeared very effective, since both designers, scientists, and health care workers

started to use this Energymeter continuously to indicate a child's activity level. Another example was the "Insight session" at November 26th, during which designers and scientists together visited the Child Oncology Department and looked for design solutions. *"It really enabled me to get feeling with the topic"* (Designer LaSenzo, May 27th, 2014). Second, during the project, internal communication means arose based on indicated needs by designers and scientists. From April 2014, when over 20 students were involved, a weekly newsletter was written by the social scientist to keep everyone posted. Also, multiple Skypesessions were organized with the medical scientists and the designers and students to reach mutual understanding regarding the interventions. Also, in February, when the second part of the project started, the scientists commenced writing a grant proposal to extend the project, but they really needed the input from the designers. Working towards such a specific goal that demanded a rigid document created commitment among all designers, health care workers, and scientists. *"The grant application made me realize how large this project actually was. Developments in supportive care go really slow and this funding provides us with the chance to really make some difference!"* (Dietician, June 18th, 2014). Third, the common goals that were set during the project kick off were continuously repeated and eventually reached, which facilitated commitment among both designers and scientists. Designers saw emerge potential interventions that would be really implemented in clinical practice since the health care workers and medical scientists were so enthusiastic, and scientists saw possibilities of working towards a large quantitative trial, to measure the effects of the interventions on eating and physical behaviour.

Not fitting in any of the enabling factors identified in literature (see Table 2), was "energy". Remarkably, multiple respondents emphasized the energy and synergy that flowed among the team: *"The team is highly vigorous, everyone is enthusiastic, the project is surrounded by a giant energy."* (Designer 4Building, May 23rd, 2014). Another enabler involved "allocation of responsibilities" Roles were clearly and naturally allocated by matching designers and researchers to project phases based on their specialism (see Data and methods, paragraph about *Prototyping (February-May 2014).* Although not mentioned in the interviews, it of course helped the project that there was a 100.000 euro budget, a year of time, and institutional support (project could be conducted within office hours).

Enablers from literature that were not prevalent in our project were: "facilitator to ease communication", "Leader who defines common problem and language". All other enablers from literature were playing a role.

DISCUSSION

The project was perceived as a large success among its transdisciplinary team members. This was particularly caused by the micro- and meso-enablers. The receptive attitude and humorous character of the individual designers and scientists predisposed the energetic atmosphere among the team. This was reinforced by shared terminology caused by participatory design-methods, common goals, and internal communication means, leading to a synergetic, transdisciplinary project.

Most prevailing barriers appeared a lack of integrative skills among students, which caused delay in intervention prototyping. Another barrier was unstable membership, detected between conceptualization and prototyping phase: other designers became active and students were involved. It took a lot of effort to facilitate shared understanding, and although a design toolkit helped a bit, a lot of pushing by the professional designers and researchers had to occur to motivate the students.

The surplus of enablers at the micro- and mesolevel might have been caused by integrating the design and medical science-disciplines. In the medical field, collaboration is essential in order to ensure quality health care and teamwork is the main context in which collaborative patient-centered care is provided (King 1990). Designers, in turn, are used to fulfill a facilitating, intermediating role. They can communicate with all specialisms and integrate the (often mismatching) inputs from specialisms (Stappers 2007).

Design-science collaboration might be of particular relevance for the medical discipline, with a rather rigid and longitudinal research character. In this project, designers accelerated research, by providing means of creative experimentation and reflection. Therefore, the potential benefit of such collaboration is more profound when designers work with medical scholars rather than (for instance) computer scientists. Rust (2004 2007) also emphasized that designers advance scientific research, by providing means of experimentation and reflection.

THEORETICAL IMPLICATIONS

To our knowledge, research on designer-scientist collaboration has been scarce. Our study helps to understand the nature of collaboration between scientists and designers, using concepts from interdisciplinarity as a model for analysis. This paper's contribution to understanding the nature of designer-scientist collaboration is threefold. First, we developed a conceptual framework (comprising micro-, meso-, and macrolevels of factors) categorizing barriers and enablers of collaboration. Existing literature did mention some facilitating and impeding factors, but its description was rather unstructured. Structured insight might help to understand the nature of cooperation better. Second, previously described enablers and barriers were rather general. We enriched them by our case study. For instance, by showing that the well-known enabler of "shared terminology" consisted of internal communication means, common goals, and participatory design tools, we enriched and illustrated existing theory. Third, we expanded the list of enablers and barriers. For instance, at the meso-level, energy had

not been described as a separate enabler.

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