INTERNATIONAL DESIGN CONFERENCE - DESIGN 2010
Dubrovnik - Croatia, May 17 - 20, 2010.

DESIGN 2010

COLLABORATION BETWEEN DESIGNERS AND SCIENTISTS IN THE CONTEXT OF SCIENTIFIC RESEARCH: A LITERATURE REVIEW

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Keywords: design, science, collaboration, interdisciplinary, scientific research, design research

1. Introduction

Science and technology are important elements for human development and well being. It is assumed that design (specifically product/industrial design) can play an important role in the advancement of science and technology, as highlighted in the Lord Sainsbury Review on Science and Innovation published in 2007 in the UK. Lord Sainsbury refers to design as a mean of accelerating scientific innovation and highlights that "evidence suggests that the use of design helps scientists to develop commercial applications for their work while it is still at the research stage or at the outset of the technology". Collaboration between scientists and designers is happening, especially in the fields of medical and testing equipment and in commercial applications of biomimicry, but there is little scholarly research into collaboration between designers and scientists in the context of scientific research.

This paper examines current literature on collaboration between designers and scientists; in particular, it looks for theoretical explanation and examples of collaborative work between product designers and scientists in the context of scientific research. It also argues that studies in interdisciplinarity can be use as a model to understand such collaboration in the context of scientific research.

The paper starts with a review of the different positions of design scholars with regards to the similarities and differences between scientists and designers. It then explores views on the difference between design research[1] and scientific research, followed by a summary of work on the collaboration between designers and scientists. The paper then discusses why collaborative work between designers and scientists can be explained in the context of interdisciplinary work, and proposes areas in which literature on interdisciplinarity might provide a useful perspective.

Although all design disciplines can potentially play an important role in collaboration with science, this study refers only to the sub discipline of Industrial/product design (since this is the particular interest of the authors). In the same way and in order to limit its scope, it only refers to the natural sciences (Physics, chemistry, etc) and the applied sciences (Engineering, Medicine, etc) leaving aside the social (Sociology, anthropology, etc) and the formal (Mathematics, statistics, etc) sciences.

This paper is part of a wider project examining the relationship between product design and scientific research[2]. It is anticipated that the conclusions of this paper will provide insights for further development of that project and for scholarly research in the area of design, science and interdisciplinary.

2. Perspectives on design and science

This section aims to explore extant literature on the relationship between design and science.

It is apparent that design researchers have made substantial efforts in trying to identify the differences and commonalities that may exist between design and scientific activity. These efforts became evident in the decade of the 1960's, when a number of attempts to make design a scientific discipline were undertaken [Cross 2007]. This has underpinned the design discourse in regards to its relation to science ever since. However, in spite of the efforts made by the design methods researchers to "scientice" design in that time, most current literature agrees that design is a fundamentally different activity from science.

In 1981, Bruce Archer identified design as a separate "range of disciplines" from those of science, and referred to design as "one of the broad areas of man's concerns" together with science and the humanities.

In a similar line of thought, Cross et al. (1981) argued that design and science are fundamentally different yet design scholars, even though they recognize this differentiation, tend to "interpret design in ways similar to those in which science in interpreted". The authors sustained that attempts to relate design to science, are more based in the values of science: "objectivity, rationality and universalism" rather than in its methods. However, Cross et al warned that there is not an "epistemologically coherent and historically valid" concept of science and therefore, it is not convenient to compare design to science. At the same time, Cross et al proposed that instead of science, technological activity can be used as an alternative model for the construction of a vision of what design might be. They argued that the practical nature of technological endeavour, its use of a varied range of knowledge (e.g. Scientific, craft, design, organizational and managerial), and "the fact that (much of it) takes place in an organizational context" are common elements within design practice. Cross reconsidered his views in a later paper [2001], saying that design can stand on its own and concluding that it should recognize its own "intellectual culture". He argued that rather than borrowing elements from science and arts, designers should learn from their "histories and traditions", and should focus efforts in trying to understand and evolve their own, based on a "reflective practice of design".

Other authors draw on epistemological differences to distinguish design from science: For instance Bonsiepe [2007] suggests that design and science are different since the first looks for "designability" and the latter seeks "cognition", and scientists produce "new knowledge" while designers create "new experiences" for people. However, he also recognizes that designers and scientists both proceed experimentally. From a different perspective, Krippendorff (2007) proposes that design and science are incommensurable, because both activities pursue "unlike epistemologies"; while science is concerned with what already exists and is observable, design is preoccupied with what "will" exist and is "unobservable". He also indicates that scientists are mostly interested in the "truth of their propositions", contrasting to designers concern with the "plausibility and compellingness of their proposals". Krippendorff also points out that scientist look for "generalisations, abstract theories or general laws" as opposed to the designer, who pursues plausible "courses of action", and that this explains the scientists' preference for abstract mathematical explanations and the designers' predilection for images, figurative models and prototypes"

Although a number of design scholars make a clear distinction between design and science, some others still advocate the idea of design as a science. For example, Schneider (2007) argues that design has now evolved and reached certain conditions so it has become a scientific discipline. This means that the discussion on this subject is not over, and a shift towards the idea of design as a scientific activity may happen in the future.

It can be concluded that some design scholars currently recognize that the differences between design and science are greater than their commonalities, and this makes design an independent discipline and not a form of science. A summary of the differences and commonalities of design and science according to design scholars is presented in the following table:

Table 1. Differences and commonalities between design and science according to design scholars

	DESIGN	SCIENCE
Bonsiepe	Concerned with "Designability"	Concerned with Cognition
Bonsiepe	Generates new experiences	Generate new knowledge
Krippendorff	Explores the unobservable	Explore the observable

Krippendorff	Deals with the inexistent	Deal with the existent
Krippendorff	Seeks plausibility and compellingness	Seek truth
Krippendorff	Produce courses of actions	Produce generalisations, abstract theory, general laws
Krippendorff	Prefer images, figurative models, prototypes	Prefer abstract mathematical explanations
	COMMON TO DESIGN AND SCIENCE	
Archer	Both are composed of a range of disciplines	
Bonsiepe	Both proceed experimentally	

It is apparent that design researchers have examined design and science to understand how they relate to each other in relation to their object of study and practice methods and outputs. However, they have not sought to understand how this relation can affect collaborative work. This evidences a knowledge gap and supports the need for further research.

3. Design research vs. scietific research

Whilst there are evident differences between design practice and scientific practice, there is also distinctions to be made between design research and scientific research. This is important since differences and commonalities in research practices can potentially become barriers or enablers for a successful collaboration. This section seeks to present work that has explored the differences and similarities explicitly between design research and scientific research.

The academic discourse about design research and scientific research is entangled with that of designers and scientists, and emphasizes that both activities as clearly different[3]. Archer (1981) for example, maintains that design research is not equitable to scientific research; nevertheless, he argues that design research can use the methods of scientific research as well as those of "designerly enquiry".

Eeekels and Roozemburg (1991) argue that both design and scientific research have an equal number of stages and that there is a certain degree of equivalence between them. At the same time, they also claim that there are several differences between design research and scientific research:

- Each has a different epistemological object; while for scientific research is to know
- (theoretical), for design research is to create (practical).
- The relation between the stages of design research and scientific research is of a dialectic
- nature: (Observational/Analytical, Inductive/synthetic, Deductive/simulating, Testing /evaluating and Evaluating/deciding)
- The output of both scientific and design research is very different; while scientific research
- generates knowledge and adds to the realm of mind, design research produces cultural creations that are added to the realm of material reality.

In the same way, Fallman (2007) compares research in design and in science, establishing a parallel that distinguishes research-oriented design (aligned with design) from design-oriented research (aligned with science). In his view, science's (and design-oriented research's) main purpose is "to produce knowledge and to seek the truth", whereas design (and research-oriented design) seeks to "create and give form to previously nonexistent artefacts".

As in the case of the comparison between design and science, there are also authors who claim that there is not a clear distinction between design research and scientific research. Glanville (1999) for example, maintains that scientific research is a design activity in which the researcher not only designs experiments, but also acts as a designer. They (the scientific researchers) do design while conducting their experiments, by "finding commonalities (simplification)", and by bringing them together as "patterns (explanatory principles, theories)". Glanville argues that research is in fact, a "restricted" form of design. Bonsiepe (2007) on the other hand recognizes that designers and scientists have a common ground in their approaches to research: They both "engage in 'thinkering', proceeding experimentally. He also argues that the practice of design nowadays involves the use of scientific knowledge and research.

This section has demonstrated that design scholars recognize both similarities and differences between design research and scientific research, as summarized in the following table:

Table 2. Differences and commonalities between design research and scientific research according to design scholars

	DESIGN RESEARCH	SCIENTIFIC RESEARCH
Eekels & Roozemburg	Serves to create practical outcomes and generates cultural creations/artefacts	Serves to generates knowledge and theoretical outcomes
Eekels & Roozemburg	Adds to the realm of material reality	Adds to the realm of mind
	COMMON TO DESIGN RESEARCH AND SCIENTIFIC RESEARCH	
Eekels & Roozemburg	Cycles are equal in number and comparable. Design research: Observation/ Induction/ Deduction/ Testing/ Evaluation Scientific research: Analysis/ Synthesis/ Simulation/ Evaluation/ Decision	
Bonsiepe	Researchers engage in "thinkering"	
Bonsiepe	Researchers proceed experimentally	
Bonsiepe Archer	Researchers make use of scientific knowledge	
Glanville	Researchers do design while researching	

Additionally, it seems that design researchers have not explored the impact of design research practice in the pursuit of scientific enquiry. Once again, a knowledge gap is apparent, indicating a new research opportunity.

4. Collaboration between designers and scientists

In contrast to the discussion about how design and science relate to each other, or how design research and scientific research compare, little work has been carried out in relation to how designers and scientists collaborate in scientific research. The lack of literature on this subject does not mean an absence of collaborative interaction between designers and scientists. For example, in the field of bioscience, there is a plethora of commercial, academic and institutional initiatives centred on this type of collaboration around the world[4]. However, access to useful information about these initiatives is limited.

Some literature on collaboration between designers and professionals from other fields could be useful to help understand collaboration between designers and scientists. For example, Squires and Barnes' book "Creating Breakthrough ideas: The collaboration of Anthropologists and Designers in the Product Development industry" (2002) describes collaboration between social scientists and designers. Even though the book covers several aspects of collaboration between social scientists and designers, it does not focus on collaboration in the context of scientific research, remaining instead in the realm of product development.

There are however, two papers written by Chris Rust (2004, 2007) that explore collaboration between designers and scientists in the context of scientific research. In his first paper, Rust claims that although scientific pursuit (discovery) is different from that of design (invention), it may be possible to initiate collaboration between both "traditions" serving both of their aims. Rust proposes that designers' abilities to "image new scenarios, and to create a "practical environment" and "experimental artefacts" may be of use to scientists to select or even generate routes of scientific enquiry. Rust states that there is a "creative dimension" in scientific research and that designers can contribute to it. Rust gives examples of collaboration between scientists and designers, and concludes that designers can contribute to scientific research by:

- Constructing models of representation and simulation that allow scientists to unlock their tacit or implicit knowledge. These artefacts can be collected and organised to give researchers a holistic view of their work, allowing them to reflect on their processes and unlock their own tacit knowledge.
- Finding ways to apply scientists' underlying theories and to prototype ideas meeting the
- different project stakeholders' agendas.
- Developing prototypes that permit either quick or rigorous testing of ideas.

- Challenging scientists' perceptions on their data by being exposed to designers' representations, which can become a catalyst for new research routes or ideas.
- Producing models that free tacit knowledge and stimulate new ideas.
- Lastly, Rust highlights two barriers to effective collaboration with scientists:
- A poor designers' self-image: Designers may think that their role within a scientific research
- project is not related to its core business (generating knowledge) and as consequence of this they can be relegated to a subsidiary role.
- Possible Collaborators may not recognise designers' contribution.

Even though Rust offers an interesting perspective on interdisciplinary collaboration, identifying both opportunities and barriers for designers in collaborative research, he does not present empirical or firsthand evidence to support his claims. Although some of the papers cited in support of his argument show a reflection on research outputs and research methods, they do not look at the specifics of interdisciplinary collaboration, or reflect on the experiences of the researchers in the context of interdisciplinary work. This opens up opportunities for further empirical exploration of collaborative work between designers and scientists, so Rust's findings can be debated and hopefully expanded and complemented.

In his newest paper Rust (2007) reflects on how creative disciplines (art and design) can contribute to scientific research. Highlighting that designers may be better suited for undertaking research activities than artists. Rust argues that "the concept of investigating/evaluating the outcomes of their work is embedded in the culture of many design disciplines". Amongst other examples, Rust presents a collaborative project between a design group composed of a filmmaker, a product designer, and a group of scientists. Their collaboration aims to develop video material that communicates to the public certain "molecular actions of nanotechnology". Rust offers an explanation on how it is necessary to create visual metaphors that the general public can understand and that at the same time "remain true to the physicists' scientific understanding" of the phenomena. Rust highlights the communication difficulties the participants had due to the lack of "any shared formal language". Rust concludes outlining "tentative principles" for interdisciplinary research between creative people and scientists:

- Some research outcomes can be valid but not easily recognised or stated by the researchers.
- Some contribution to research can be "generative" and not necessarily "specific".
- "Generative" in the sense that creative people can contribute to research with material that helps scientists to take their research in new directions, and non "specific" in the sense that creatives shouldn't make "strong judgements" about how "significant" their findings are for the research.
- Regardless of the type of contribution made by creative people and of how intentional and
- purposive it is, only the "audience can determine" what is relevant.
- Methods of creative research reveal "tacit" knowledge, but also "tacit" knowledge is used to
- shape those methods.
- In order to be recognised as researchers, artists and designers should: Specify their research
- subject and their motivation, Show a good understanding of their research state of affairs
- (past and present) in their subject of study, Make use of an appropriate research method, and be able to communicate their findings to the wider community.

Even if Rust has a good insight into what can be perceived as an inexplicit or "tacit" contribution from creative people to research, a substantial part of the evidence that supports his claims (personal conversations with artist and designers) is not presented or accessible. At the same time, it is noticeable that conclusions have been mainly drawn from the views of the participant designers; conclusions could have been different had the views of the involved scientists been considered in a greater extent. Rust also claims that there are differences between artistic and design contribution but no explicit details of this difference are presented; this perhaps indicates the need for further study to make them explicit.

It can be concluded that designers may have a meaningful role in scientific research by:

- Designing Artefacts for testing and experimentation
- Ideating Scenarios

- Finding applications for scientific research outcomes
- Visualizing scientific ideas

It can also be concluded that these actions may benefit scientific research by:

- Unlocking "tacit" knowledge
- Connecting scientists with the non scientist, and helping to disseminate scientific knowledge
- amongst the general population
- Facilitating the advancement of scientific research, by providing means of experimentation
- and reflection
- Challenging scientists' perceptions and encouraging the pursuit of new research directions.

Further study on collaboration between designers and scientists should present primary evidence and look at the views of both designers and scientists. This to confirm, contradict, expand or complement Rust's findings. This will also probably contribute to design and science knowledge by finding new insight on the subject and perhaps uncovering other possible contributions from designers to scientific research.

5. Designers and interdisciplinary work

Bearing in mind the differences between designers and scientists and their identification with separate disciplines, and the recognition of design and science as interdisciplinary activities [Schneider [2007]; Friedman [2003], a study that looks at designers interacting with other professional in collaborative endeavour can be placed in the context of interdisciplinarity.

There is extensive literature that looks at the specifics of interdisciplinary collaboration between science and other disciplines; moreover, almost any writing that examines interdisciplinarity, eventually looks at a scientific discipline. However, with the exception of the works previously mentioned, studies that look specifically at collaboration between designers and scientists seem not to be available. Nevertheless, even if not directly referred to design, current literature in interdisciplinary studies seems to be potentially useful to underpin a study in collaborative research between designers and scientists. In a initial exploration, some relevant papers have been identified that may help to:

- Define the type and models of collaboration to compare, set boundaries and identify
- particularities in design and science collaboration. Klein (2005), Epstein (2005)
- Identify potential problems in collaborative interdisciplinary endeavour and outline possible
- ways to overcome them. Reich & Reich (2006), Klein (2005)
- Identify elements that enhance collaboration. Epstein (2005)

5.1 Models of collaboration

A number of different models have been proposed to classify interdisciplinary collaboration. Each of them could be used to frame and analyse interdisciplinary collaboration between designers and scientists. However, it seems that every one of them is suited to certain aspects of collaborative work. For example, Bass (1975) (cited in Klein (2005) proposes categories of interdisciplinary collaboration, looking at the orientation, structure, constraints and leadership of collaborative effort. In this categorisation, activity in interdisciplinary collaboration can be:

- Un-oriented and unstructured: Without a particular research focus and structure of work.
- Oriented unstructured: Thematically more focused but without defined times and roles.
- Oriented structured without constraints: Common focus and programmed; no individual
- leadership.
- Oriented structured with constraint: Programmed to foster direct contact and communication.
- Under centralised executive control: Research "under centralised administrative and
- operational control".

This classification is potentially useful to help understanding the nature of the activities carried in design and science collaborations and their relation to the level of success and any potential issues and problems.

Klein (2005) also explains how Simon and Goodge categorise interaction levels in interdisciplinary projects, according to the meaningfulness of its contribution:

- Background or Context Information.
- Elaboration or explanation of findings.
- Definition of important variables or categories.
- Creative combination of ethnography and multivariable approaches in research, analysis and
- interpretation.

This categorization can be useful to compare the level of integration between design and science disciplines in collaborative endeavour and to describe roles, membership and power issues.

Epstein (2005) presents John Steiner's (1998) categorisation of interdisciplinary work according to patterns of collaboration. This categorisation looks at teams' working structure, role forming and performing, and at their level of integration; its proposed categories are:

- Distributed: Characterised by informality and centred on exchange of ideas and information.
- Complementary: Each individual contributes according to his/her own field of expertise.
- Family: People "interchange roles" outside their own disciplinary boundaries.
- Integrative: Collective undertake in which the roles are set by research questions and
- people's experience rather than disciplinary identities.

Steiner's model can be employed to explain the effectiveness of collaboration between designers and scientists according to role distribution, and levels of participants' commitment and engagement.

Although these models seem appropriate to look at particular aspects of collaboration, they are not individually comprehensive or textually suited for the potential particularities of design and science collaboration. However, some of their elements can be used to build a model to help explain collaboration between designers and scientists in scientific research.

These elements have been integrated in a new model that looks at these questions: What is the designers' level of commitment to the research and what is their research group membership? How direct or indirect can the designers' activity be in regards to the research questions? How well defined or blurred the designers' disciplinary identity is? How significant is the designers' power to decide on the direction of the research?

This model initially proposes 4 levels of research engagement:

- Research in which designers act as a "design suppliers" and in which the design task are determined by the research group. The design tasks are not directly related to the research questions and designers have no research membership.
- Designers are members of the research group, but their tasks are associated specifically to team agreed "design" issues. Tasks are not directly related to the research questions.
- Research in which the designers' activity is directly related to the research questions but the research agenda is set and lead by the scientists. Disciplinary roles are kept.
- Research in which designers and scientists team up to define the research questions and to find its answers. Disciplinary roles are blurred and activities are defined by research questions

5.2 Potential problems

Literature on interdisciplinarity gives importance to the identification of potential problems in collaborative work. Klein (2005) for instance, presents an extensive and comprehensive list of potential problems in interdisciplinary collaboration. They can be related to the personal characteristics and attitudes of the researcher, to the context in which the research is carried (physical, institutional, legal, etc.), to the disciplinary background of the researchers and their inherent perception of the world and to group dynamics. These are the potential problems identified by Klein:

- Resistance to innovation, mistrust, insecurity, marginality produced by social and psychological impediments.
- Participants may lack integrative skills, system thinking and/or familiarity with interdisciplinarity.
- Strong groups can be undermined by an unstable membership and unwillingness to take risks.

- Projects can encounter time and access to equipment constrains, rigid budget and administrative categories or restrictive legal mandates and policies.
- Progress can be deterred by lack of incentives and inadequate reward system.
- Disciplinary defaulting can happen.
- Conflict may appear over technical issues (definition of problems, research methodologies, and scheduling) or associated with interpersonal issues (leadership style and disciplinary ethnocentrism).
- Teams can suffer from "excessive organisational baggage": fixed perception of others, status in the organisation, preconceived ideas of roles and different understanding of problems.

From a different perspective, Reich et al. (2006) identify the struggle for power as a source of conflict in interdisciplinary work, highlighting "tokenism" (disciplines represented in teams but not included in decision making processes), and the silencing of "lower status" disciplines by hierarchical structures. The authors also highlight "disciplinary policing", or reinforcement of discipline boundaries grounded on participants' belief of a "disciplinary superiority".

It can be concluded that collaboration between designers and scientists can potentially be hindered by any of the problems identified by Klein and Reich et al. However, it seems that there may be other potential problems that are inherent to the specific collaboration between designers and scientists. For example, as suggested by Rust (2007), difficulties in the communication between designers and scientists due to the lack of common specialised language can happen, as well as problems making tacit contribution explicit. Therefore, any study on interdisciplinary collaboration between designers and scientists, should seek to identify both, generic and specific problems.

5.3 Enhancing collaboration

Although the investigation of the problems that may arise in interdisciplinary collaboration can be fundamental in understanding collaboration between designers and scientists, reflecting on studies that look at how to improve collaboration can be also useful.

Epstein (2005) for example, examines different aspects of interdisciplinary work and puts forward suggestions for enhancing collaborative work. The author looks at the attitude of researchers, suggesting that they need to be receptive, open minded (especially with regards to other disciplines), ready and proactive in learning from others, and to have a sense of humour. She highlights that personal empathy between researchers plays an important role in the success of scientific research. She looks also at communication, proposing that "fundamental terminology should be established early and reviewed regularly" and that particular attention should be paid to unnoticed specialised use of same words that have different meanings in each discipline. She also comments on time, explaining that interdisciplinary collaboration demands more time than disciplinary work to achieve the same goals, so special care should be taken when preparing research budgets. Epstein emphasises the importance of proximity between researchers, arguing that face-to-face contact is fundamental for interdisciplinary collaboration. Mentioning the importance of having institutional support, the author asserts that interdisciplinary research requires more funding than disciplinary research (to pay for the integration costs) and that it is more difficult for interdisciplinary research groups to obtain funding. Epstein examines the importance of roles in interdisciplinary work; the author suggests that it is important to have clear allocation of responsibilities. She proposes that it is vital to have a leader to "define the common problem and the language in which to discuss it, to set priorities and even to target publications" (though the group may opt for an equally valid model in which decisions are taken by consensus). Also, she suggests that someone should have the role of "facilitator" to ease communication between members of the team. Finally, Epstein explains that the research topics should be equally interesting for all disciplines involved and that ideally, none of them should be closer than the others to a solution at the beginning of the collaboration.

It can be concluded from this section that designers may have some inherent characteristics that may help them to engage effectively in collaborative research. For example, their "attitude" can be an advantage to collaborative work, since they "can communicate with all specialisms... (and)... integrate the (often mismatching) inputs from specialisms" [Stappers 2007]. It also seems that designers may be naturally suited to play the role of facilitator within research groups, given their abilities to

communicate by conventional means but also through visual methods. However it is important to pay attention to two other aspects mentioned by Epstein. First, if a scientist takes the role of leadership within an interdisciplinary scientific research group, the group should be careful to avoid hierarchical structuring resulting in designers loosing decision making power. Second, collaboration between designers and scientists in the context of scientific research may not always have a single common research interest for all participants, as seen in the model of research engagement proposed at the end of section 4.1.of this paper. For this reason, designers and scientists may have to maintain effective group communication and to make additional efforts to keep the research useful for the whole group.

6. Conclusions

This paper has examined the different positions of design scholars regarding the similarities and differences between scientists and designers. It has also explored views on the difference between design research and scientific research, and has summarised work on the collaboration between designers and scientists. This document has also discussed why collaborative work between designers and scientists can be explained in the context of interdisciplinary work, and has proposed areas in which literature on interdisciplinarity might provide a useful perspective.

It can be concluded that current literature recognises the similarities and differences between designers and scientists. Although they are concerned with different epistemologies, with designers focusing on creation and scientist on discovery, both proceed experimentally.

It can also be said that design scholars believe that the main differences between scientific research and design research are in their objectives and outcomes. While design research aims for practical outcomes that add to the realm of material reality, scientific research aims for knowledge generation that adds to the realm of the mind. Additionally, it seems that designers and scientists involved in research activities have more in common than previously believed.

Most authors are not particularly interested in searching for those aspects of the practice of design and science that may allow interdisciplinary collaboration between designers and scientists in the context of scientific research. However, some literature suggests that designers may have a meaningful role in scientific research; by unlocking "tacit" knowledge; by connecting scientists with the non scientist; and by helping to disseminate scientific knowledge to the general population. Designers may also facilitate the advancement of scientific research by providing means of experimentation and reflection, by challenging scientists' perceptions and encouraging the pursuit of new research directions.

The balance of the argument suggests that current literature in interdisciplinary studies seems to be potentially useful in underpinning a study on collaboration between designers and scientists, by asking:

- What are the roles that a designer can play in interdisciplinary collaboration in the context of scientific research?
- What characteristics of a designer may facilitate or hinder their contribution in collaborative work?
- How should the differences and commonalities between designers and scientists working collaboratively be used to enhance the pursuit of scientific research?

This paper suggests that further study on collaboration between designers and scientists is needed, to produce "first hand" evidence and to look at the views of both designers and scientists. This could include case studies that exemplify different levels of designers' involvement in scientific research; in either new or existing. This will hopefully help to find new insight on the subject, perhaps revealing other possible aspects and issues of collaboration between designers and scientists in scientific research.

Notes

[1] *By design research this paper means the research process that designers go through before and during design projects. It does not mean the research activity that scholars (design researchers) conduct looking at the practice and theory of design.*

[2] *Further information in the "Design in Science" project in: http://www.ifm.eng.cam.ac.uk/imrc/eip/design.html*

[3]*It is noticeable that some authors make no distinction between research and scientific research, and between science and scientific research: They instinctively draw comparisons between design and scientific research and between design and research as if they were the same.*

[4]*A few good examples of designers and scientists collaborating in academic and commercial research environments can be found on the web:*
Simbiotica (University of Western Australia http://www.symbiotica.uwa.edu.au/welcome),
Material Belief (Goldsmith University http://www.materialbeliefs.com/),
Biomimicry Guild (http://www.biomimicryguild.com/)

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