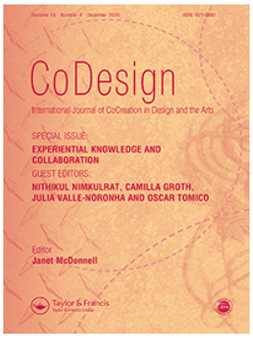

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CoDesign

International Journal of CoCreation in Design and the Arts

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ncdn20

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To cite this article: Camilla Groth , Margherita Pevere , Kirsi Niinimäki & Pirjo Kääriäinen (2020) Conditions for experiential knowledge exchange in collaborative research across the sciences and creative practice, CoDesign, 16:4, 328-344, DOI: 10.1080/15710882.2020.1821713

To link to this article: https://doi.org/10.1080/15710882.2020.1821713

Published online: 17 Sep 2020.

CODESIGN
2020, VOL. 16, NO. 4, 328–344
https://doi.org/10.1080/15710882.2020.1821713

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Conditions for experiential knowledge exchange in collaborative research across the sciences and creative practice

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ABSTRACT

Interdisciplinary research across the sciences and creative practice offers potential to explore new areas of knowledge previously hidden between disciplines. However, diverging epistemology and expectations make collaboration difficult. We interviewed 11 researchers working in projects that combined scientific and creative practice research, to investigate how they dealt with different epistemological approaches. In some cases, the discrepancies that were first experienced as hindrances turned into enablers, opening up new vistas for learning. Our findings show that the prerequisites for experiential knowledge transfer need to be built consciously by engaging in hands-on practices and shared cognitive activities that may extend beyond the personal comfort zone. Furthermore, the common goals and research questions need to be motivating for all involved. Although academic research funding agents encourage interdisciplinary research, funding alone is not sufficient to motivate people to work and truly learn together. By combining different types of knowledge in co-creation processes, participants are able to better share each other's views and construct a multifaceted understanding. An analysis of the interviews suggests how a conscious development of interdisciplinary practice helps educate thinkers and makers to feel comfortable in the unsettling zone between disciplinary boundaries, and thus contribute to innovative research.

ARTICLE HISTORY
Received 2 April 2020
Accepted 20 August 2020

KEYWORDS
Creative practice; science; interdisciplinary research; collaboration; experiential knowledge

1. Introduction

The architect John Zeisel wrote in the 1980s: 'People look to cooperate with others when they want to do more than they can do alone' (1981/2006, 47). Over the last decades, the research landscape has changed rapidly as a result of globalisation and the related emergence of new complex phenomena. General research policies guide researchers towards actively solving material, societal and global challenges through problem-oriented, solution-focused and collaborative research strategies (Lamy 2017). In such efforts, collaboration across disciplinary borders is inevitable: the issues are multifaceted, complex and

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involve several networks and relationships between multiple actors, as well as deep domain-specific knowledge. Today Zeisel's words are more relevant than ever.

Those in creative fields are also being encouraged to transgress the disciplinary border, and the past 20 years has seen a new convergence between creative and scientific research (Borgdorff, Peters, and Pinch 2020, 1). The Arts and Humanities Research Council advocates collaborative projects between science, arts and humanities, claiming significant potential in such collaboration while also pointing out the limitations of using scientific approaches in isolation to tackle societal challenges (AHRC, n.d.). Similarly, many European funding agents have formulated special research programmes around the subject, such as Horizon 2020, the Organisation for Economic Co-operation and Development (OECD), the Academy of Finland, Volkswagen Stiftung, Robert Bosch Stiftung, and the Kone Foundation, to name a few.

Discussions on the possible challenges and benefits of fundamentally different epistemologies meeting are now topical. However, well-established best practices that would work regardless of context are yet to be modelled. Many of the researchers that we interviewed did not have a strategy for collaboration prior to starting their project, while some said that they tried to invent ways of collaborating as they went along.

Different constellations such as *intradisciplinary, multidisciplinary, cross-disciplinary, interdisciplinary, transdisciplinary*, or even *non-disciplinary* have been discussed from different viewpoints in the creative field and the humanities (Zeisel, 2006, pp 75–76; Peralta and Moultrie 2010; Borgdorff, Peters, and Pinch 2020; Borgdorff 2012; Nicolescu 2014). Challenges, benefits, pitfalls and new understandings have been compared and the use of the results questioned (Grix 2010; Niinimäki, Tanttu, and Kohtala 2017; Niinimäki 2018, 2019; Pirinen 2016; Solberg 2018; Scott 2006; Shildrick, Carnie, and Wright 2017).

This article builds on Marilyn Stember's (1991) definition of what these different terms mean, and the level of 'sharing' in these types of interactions. Stember (ibid., p 2) recognises three types of arguments for collaboration across disciplines: *the intellectual* – ideas in any field are enriched by the theories, concepts and methods of another field; *the practical* – problems of the world are not organised according to the academic disciplines; and *the pedagogical* – learning is hindered by fragmentation in the curriculum. Stember's modes of interaction between people working in diverse collaborations are further explained and developed by Alexander Refsum Jensenius (2016):

- Intradisciplinary: working within one's own single discipline.
- Multidisciplinary: people from different disciplines working together, but each person drawing on their particular disciplinary knowledge.
- Cross-disciplinary: viewing one discipline from the perspective of another discipline.
- Interdisciplinary: integrating knowledge and methods from multiple different disciplines, synthesising the different approaches.
- Transdisciplinary: creating a unity of intellectual frameworks beyond disciplinary perspectives.

These definitions show how complex collaborative efforts are between different disciplines and their respective traditions, paradigms, ontology and epistemology. Entirely transdisciplinary work is rare, and even interdisciplinary work may be challenging to

achieve (Stember 1991, 6). However, the complex research environments of today require researchers to confront these challenges.

Collaboration between creative practices and science is a rich and diverse territory, and any attempt to chart it comprehensively will remain provisional. Such diversity includes art and science practice pursued in dedicated biology laboratories such as the pioneering SymbioticA at the University of Western Australia (www.symbiotica.uwa.edu.au), Biofilia – Base for Biological Arts at Aalto University (FI) (www.aalto.fi/en/biofilia), or The Centre for Biotechnology and Interdisciplinary Studies at Rensselaer (US) (www.biotech.rpi.edu); by networks such as the Finnish Bioart Society (https://bioartsociety.fi/, see also Berger et al. 2020); and the International Symposium on Electronic Art (ISEA) and Ars Electronica. Innovative study curricula explicitly focus on cross-pollination of disciplines, such as the bachelor degree programme Cross-Disciplinary Strategies – Applied Studies in Art, Science, Philosophy, and Global Challenges at the University of Applied Arts Vienna (www.dieangewandte.at/cds). Research on innovative materials is the core of recent projects such as The Cluster »Matters of Activity. Image Space Material« (www.matters-of-activity.de/en); Mind the Fungi at the Technische Universität Berlin and Art Laboratory Berlin (www.mikrobiologie.tu-berlin.de/menue/forschung/entwicklung_pilzbasierter_werkstoffe/parameter/en); and the CHEMARTS Platform at Aalto University (chemarts.aalto.fi).

Several recent conferences invited contributions on interdisciplinary research involving creative practices and different fields of science (cf. Nimkulrat and Groth 2018; Nimkulrat et al. 2019; Karana et al. 2019). The diversity of case studies presented in these proceedings, and in further literature (Mejía et al. 2018; Driver, Peralta, and Moultrie 2011; Vaage 2015) as well as in the examples mentioned above, suggest it may be unsuitable to draw an all-encompassing general understanding of ideal formats for collaboration, as each case needs to be framed individually. While acknowledging this diversity, the present study aims to identify challenges and opportunities for experiential knowledge exchange in such collaborations.

This study was inspired by a collaborative research project studying new biomaterials and material development that involved researchers from the fields of design, crafts, bioart, synthetic biology and biochemistry (Niinimäki, Kääriäinen, and Groth 2018). The aim of the initial project was to cross-pollinate research methods and foster experiential knowledge transfer across disciplines through co-creation workshops and discussion (cf. Karana, Pedgley, and Rognoli 2015; Sanders and Stappers 2008). The fields represented by the project's researchers contributed through diverse interests and approaches to materials and materiality, including experiential knowledge and materiality and innovation. This led to the initiation of the interview study that forms the data for this article.

For this interview study, we were interested in features that could facilitate the transformative exchange of experiential knowledge in interdisciplinary projects. The authors' backgrounds and situatedness (Haraway 1988) in the fields of crafts, design and art influence the motivations, perspective, design, literature and data analysis of the research.

This paper presents findings from the interview study of researchers working in Finland and Germany. To encompass the diverse domains that our interviewees refer to, we use *creative practices* to refer to arts, craft, design and related research, and *science* to refer to natural sciences such as biology, chemistry, physics and biotechnology. While acknowledging that these terms are simplifications, we highlight how they allow an

overarching reading of the different interdisciplinary projects in which our respondents engage.

As our interviews were anonymous, the images in this article are not linked to the study but rather serve as an example of the collaborations and co-creation contexts that were reflected on in the interviews. The projects documented in the images are not analysed in this paper.

1.1. Experiential knowledge

Experiential knowledge is the understanding that can only be gained *a posteriori*, through experience (Borgdorff 2012, p 68; Niedderer 2007; Niedderer and Reilly 2010, 5). Such understanding can be achieved through close interaction with the phenomena under study, be this through sensory interaction or mediated by tools, however it is non-discursive and tacit (Borgdorff 2012, p 69; Polanyi 1966, 5) (Figures 1 and 2).

Both the scientific and creative fields use experimentation through practice-led processes to test assumptions; during this process new questions might emerge (Candy and Edmonds 2018), which can lead to knowledge production (Borgdorff 2012, 68). Evaluations and judgements are based on previous experience and expertise that grows over time. Knowledge becomes embodied in the researcher as tacit or implicit knowledge. Within the same discipline, or between colleagues with the same research experience, experiential knowledge is easily shared.

Sharing experiential knowledge beyond disciplinary borders can be challenging, as research methods and epistemic frameworks might differ radically (Ingold 2018). However, as Ingold (2013, 3) suggests, by investigating phenomena *through practice* rather than mere observation, one can capture the experiential nature of the practice and

Figure 1. Scientists, designers and artists experiencing biomaterials through sensory perception in a workshop by Margherita Pevere. Image by Pirjo Kääriäinen.

Figure 2. Preparation of interdisciplinary workshop for material scientists, designers and artists by Margherita Pevere. Image by Pirjo Kääriäinen.

knowledge becomes transformational rather than merely documentational. What we learn changes us and becomes part of who we are. However, such change may not happen in an instant.

Borgdorff writes that there is 'something uneasy about the relationship between artistic research and the academic world' (2012, 59), meaning there are clear epistemological differences that need to be handled in such collaborations and that this process can be challenging. However, an exhaustive discussion of the epistemic differences between science practices and creative practices, as well as between scientific research and research through creative practices, is beyond the scope of this paper.

2. Research design: pilot interview and special interest interviews

As groundwork for our study, we conducted a pilot interview with an experienced researcher to understand the core framework of scientific research and research through creative practice. Based on our literary preunderstanding of relevant issues, we formulated questions for the pilot interview with a natural scientist with a background of interdisciplinary projects, including long-term collaborations with researchers in creative practices. The pilot interview highlighted the potential for knowledge production and mutual fascination between disciplines, but also friction areas and weak points, such as the different epistemological frameworks underpinning different research approaches. We eventually compared what emerged from the pilot interview with the reference literature outlined above.

Next, we approached 11 scientists and creative practitioners who had engaged in interdisciplinary projects to explore the challenges and potentials of such collaborations. Although our respondents worked for organisations or institutes with various interests,

they were all interested in cross-fertilising research and can thus be called a special interest group.

The analysis section offers insights into how the interviewees understood both their own and their collaborators' benefits from working together, and how they facilitated knowledge transfer within their groups.

2.1. The participants

We invited participants based on their recent activities and successful funding applications in the context of interdisciplinary research. We identified participants through our own connections in the field of interdisciplinary research on new materials, art and science, and related activities. We followed recommendations of other projects and researchers in a snowball manner. At the time of the study, three of the authors were based in Finland and one in Germany; we decided to address international researchers working in both countries. Our group was gender-balanced and included scientists (5) and creative practitioners (6) at different career stages: some experienced participants ran large research teams and had published more than a hundred international research papers; others were early career researchers but with a minimum of four years of experience. Apart from one, they either had or were pursuing a doctoral degree in their field. Seven interviewees worked in Finland, four in Germany.

To obtain uncensored answers we keep our interviewees anonymous. For most interviewees, interdisciplinary research covered only part of their research activity as interdisciplinary projects only last for a limited time. Some had education or training in both the arts and science fields. Their roles in the collaborative projects varied from facilitating research through funding, acquiring staff and materials, and providing and actively participating in discussions on research issues, to concrete hands-on actions and interactions with materials and other participants. Table 1 presents our dataset.

Table 1. Education, country, level of experience, main research field, interdisciplinary project area and role of participants.

Education	Country	PhD	Main research field	Interdisciplinary project area	Role in project
Creative practice with science interest	FI	2008	Design	Biomaterials	Facilitator and participant, hands-on
Science	FI	1997	Chemical engineering	Material research	Facilitator and participant
Science	FI	1980	Neuroscience	Neuroscience and art	Facilitator and discussion partner
Science/painting	FI	1987	Synthetic biology	Biomaterials, bioart	Facilitator and discussion partner
Creative practice	DE	2018	Bioart, media art	Bioart, biomaterials	Hands-on
Science/music	FI	1983	Physics polymers	Biomaterials, design	Facilitator
Science	DE	2014	Computer science	Bioart	Hands-on and facilitator
Humanities, art	FI	exp 2020	Bioart	Material research, bioart	Hands-on and discussion partner
Science	DE	1986	Microbiology	Biomaterials, design, humanities	Hands-on, facilitator, and discussion partner
Creative practice	FI	No PhD	Environmental, media and bioart	Environmental, media and bioart	Hands-on
Science	DE	1983	Physics	Biomaterials	Facilitator

2.2. The questions

Our questions explored epistemological differences and how researchers navigate these in interdisciplinary research. We asked participants about the extent of their collaboration, their role in it, what led to it and what value it brought. We explored their views on the differences and similarities between creative fields and sciences, such as research paradigms, methods, validity and beliefs. We asked about the language they used, and how collaborators communicated. We inquired into what challenges the researchers encountered, including discrepancies and friction points, but also how to navigate them and what possible benefits respondents saw in interdisciplinary collaboration. Finally, we asked about individual experiences of success or failure and what had led to these.

The semi-structured interviews (Flick 2009) took place orally (except for one conducted via email), in a conversational situation guided by a set of questions. This method has the advantage of balancing systematic data collection while allowing spontaneous observations to provide further insights. However, conversational situations might lead to rewording, which may reduce the comparability of responses. We prioritised diversity of information over comparability and compensated for this with a qualitative analysis of the interviews.

3. Analysis

Each interview was transcribed and two of the authors conducted an initial meta content analysis to see what general features emerged. Based on these, they carried out a co-analysis process to detect overlapping and common understanding, as well as issues that emerged outside the predetermined interview questions. Next, the other authors joined the analysis process and added their perspectives to the results. Based on the added content analysis (Flick 2009) we first present the general features, then elaborate on four specific themes that emerged in connection to experiential knowledge transfer.

A common attitude among the scientists was that the creative fields bring new ways of disseminating scientific research results through either their expressive display or design application. Few scientists embraced the more artistic researchers' ability to influence the scientific direction of the project, and few took into account the possibility of utilising artistic results in their own research outputs, other than through images or prototypes. However, some of the creative practitioners reported that their ideas contributed to the direction of the research through raising new research questions in their group.

Most of the creative practitioners aimed for *transdisciplinary* collaboration, whereas the scientists held a more *multidisciplinary* stance, where the two disciplines add to each other's work while maintaining their own expert areas. While most of the scientists appreciated the potential of interdisciplinary collaboration, most creative practitioners were frustrated that their partners did not understand their contribution beyond a functional purpose such as dissemination or illustration.

Some scientists highlighted how creative practitioners (especially designers) can bring in end-users' viewpoints for material development and how this benefits scientists looking for e.g. application of their research inventions. Through collaboration with artists, a few scientists could find new research angles or an emerging new research question relevant to their own discipline.

On the other hand, creative practitioners pointed out how science can inspire their research and give new impulse or rigour to it, for example with learning lab protocols (figure 3). In this way disciplines can benefit and inspire each other, furthering their own research and challenging their disciplinary understanding and even practices. However, almost all participants highlighted that if one has to compromise the quality of one's own contribution too much, collaboration becomes meaningless.

There was consensus that building trust and solid communication in collaborative research requires regular presence and common activities: opportunities of *knowing together* require people to work in the same space or facilities and engage in the research hands-on and/or through discussions on a regular basis (figure 4). Most suggested meeting every week at a minimum; some preferred daily interaction.

Figure 3. Textile designers learning lab procedures of synthetic biology. Photo by Eeva Suorlahti.

Figure 4. Scientists, designers and artists experiencing biomaterials through sensory perception in a workshop by Margherita Pevere. Photo by Eeva Suorlahti.

Project longevity was mentioned as a key factor too: short projects would be unable to affect participants' ways of thinking, or understanding their partners' different approaches. Engaging in the partners' literature and protocols may mean stepping outside of ones comfort zone, but is essential for educating oneself and each other. It also helps to build bridges and a common language for the project.

Factors that hindered collaboration were often the opposites of the enabling conditions. Trust, respect and appreciation of each other's work and attitudes were considered crucial, and if any of these failed, the collaboration could too. The creative practitioners and scientists agreed that 'personal chemistry', though hard to describe, was important when establishing collaborations.

It also became apparent that individual interests, personalities, and most importantly epistemic differences could affect collaboration even within the same discipline. Some of the interviewees noted that division into disciplines according to training or research fields may be incorrect even within their own department. Interestingly, a certain 'boundary crossing' emerged in the way both the scientists and creative practitioners related to and spoke about the materials they worked with. Although scientific research generally requires a fundamentally objective approach, some scientists were open to relate emotionally or subjectively to their materials. In contrast, some creative practitioners considered it important to relate to their material processes through a scientifically organised and systematic approach to validate their findings in science contexts and contribute to publications beyond the creative field.

While participants agreed on these points in general, their expectations of the outcomes differed, as did their understanding of successful or unsuccessful collaborations. Providing a generally valid definition of a 'successful' collaboration in interdisciplinary contexts is hardly possible given the variety of types, durations and objectives of projects. Importantly, measuring success across disciplines involves different acknowledgement systems, value systems, expectations and even career paths.

The above results were the general issues that arose in the interviews; now we look into experiential knowledge transfer. An analysis of the interviews outlined key enabling factors for experiential knowledge transfer in the interviewees' experience. We found four general themes in the interview data:

(1) Close practical collaboration and intellectual exchange: the importance of working hands-on in the same premises.
(2) Motivation to solve the same research problem: the importance of using one's own expertise in mutually new contexts.
(3) Trust, personal chemistry and the ability to leave one's own comfort zone: the importance of mutually educating each other and building a common language.
(4) Knowledge production: the importance of being open to multiple perspectives.

4. Discussion: experiential knowledge transfer in interdisciplinary research collaborations

In the following discussion we open up the four identified themes, through excerpts from the interview transcripts and showing how we came to this understanding.

4.1. The four enabling issues in experiential knowledge exchange

(1) ***Close practical collaboration and intellectual exchange: the importance of working hands-on in the same premises.***

All interviewees highlighted how intensive and regular communication was key for collaborating successfully, as it allowed the partners to nurture mutual understanding of the processes, and be clear on what needs to be done next, why and how. However, listening to each other's ideas and being ready to step outside of comfort zones while pursuing a common understanding was also highlighted.

One interviewee told us how the discussion and process of analysing results together influenced their team's understanding of new possibilities, but also that failures may bring people closer together:

> We failed completely in our first attempt, but that opened our eyes and we learned to discuss and understand different ways of doing things, and actually, failing was the key in this process of forming the group.

It was also generally understood that it takes time to find ways to work together:

> I don't think we can expect very quick results. It actually takes some time to find the right ways of doing it. I think there are very few examples of how to do this combination of research. There are not any methods for it. So, we have to do a lot of searching for ways to go forward.

(2) ***Motivation to solve the same research problem: the importance of using one's own expertise in mutually new contexts.***

Collaboration only succeeds if partners have a mutual interest in the subject and believe that they can shed light on aspects that cannot be covered by the disciplinary approach only. The respondents agreed that funding alone could not motivate research partners to work together successfully. One of the scientists, who was less pleased with their collaboration, mentioned that motivation to solve a mutual research question would have been a key enabler:

> But if we all had a common question, [...] then I would have gone straight to him and said let's start talking every week about this and see how we can do an experiment, how we can find some earlier writing and maybe go to some place and do experiments there. Then we would have a mutual interest, and that certainly is the key!

One of the creative practitioners explained:

> In our team we managed to create new methods and new materials and use areas, but we couldn't have done this without each other's help. We really needed the scientists and designers working together for this and the combination of these two ways of working led to success.

(3) ***Trust, personal chemistry and the ability to leave one's own comfort zone: the importance of mutually educating each other and building a common language.***

Most of our interviewees raised the need to build a common language and clarify the setting in which such language could be used. However, this can only happen with

mutual effort to communicate, trust and understand each other. Although funding bodies request that research positions in a funded project should be open to ensure that the best applicant is selected, many of our informants reported the importance of carefully choosing team members because personal chemistry does influence the success and motivation of the collaboration. In the words of one of our respondents:

> Complications arise in all fields, not only in collaboration with artists. It's about what kind of people are able to work together, about personal chemistries. Communication skills, but not only skills, because if we want to collaborate, we should have a common interest and know that we can learn from each other so that we are both happy to work together.

Another interviewee said:

> I think the chemistry between people is really important for the success of any collaboration, so the formation of groups might be the key to success. Because many scientists are not able to work with creative practitioners, I think we should think more about what kind of people are able to work together. And not just think that ok now we have "an artist" coming to the science lab, because that happens a lot.

Mutual respect and acknowledgement were also paramount. The creative practitioners in our cohort perceived their work as undervalued when it was used for communication only. On the other hand, the scientists did not feel comfortable if they were seen as a mere source of skills or material resources. In our interviews, the scientists mentioned the potential for communication of the creative practitioners' input and the creative practitioners mentioned the opportunity to access resources and technologies. However, these aspects were mentioned marginally, and both the scientists and creative practitioners highlighted mutual learning as the most valuable contribution.

A creative practitioner from the design field had the following experience:

> [. . .] most scientists want to stay in their own bubble, and it's not that easy to find the kind of scientist who really wants to open their mind, to see new ways of doing things. But, in a couple of the groups I worked with we really took huge steps when we trusted and respected each other. But in most cases I think that the scientists thought we were only stylists or product designers, and that's typical. They didn't think we could add value in other ways, such as by really bringing about something new or offering new knowledge.

More than one participant suggested that their team needed time and dedication to create mutual understanding and respect across disciplinary borders. One experienced scientist told us:

> We've been discussing artistic research in regular meetings for over two years now, including workshops and mutual artistic exercises, and we have even been on a retreat together, but it's taken a long time to find ways, and the right words, to communicate. We are very interested in each other's work and ideas, and we are working on a mutual paper, but we haven't been able to produce anything concrete yet.

In the attempt to understand each other, difficulties also arose. One scientist explained:

> There is a gap between us, and the gap between scientists and artists is larger than I thought it was. I believe that we can bridge this gap, but the key is that the people involved are willing to do that. Even just negotiating the words so that people just a little outside [their own discipline] could understand.

The situation requires awareness that it is difficult, but that giving up will not take one any further. Friction points should be seen more as enablers of change, where a bridge may be built, and new concepts may be developed. One of our informants claimed:

> The main point is that in order to understand more in any field there has to also be some contradictions. Somehow people can't be in concert all the time; they need to also find some friction points, some contradiction. In order to proceed from these friction points, you have to be able to communicate with the others. [. . .] In order to understand how people are in the world and how they understand the world we try to combine these different views, but first we have to bridge the concepts so that we can talk to each other.

(4) ***Knowledge production: the importance of being open to multiple perspectives.***

The different angles to 'exploring the world' and building a shared understanding of it might bring us closer to the transdisciplinary mode of knowing. An interviewee from the field of science said:

> I think artists, like scientists, are somehow exploring the world, but [artists] are more free in the way they do it. In science, much, but not all, of the scientific process is rather regulated and follows strict rules. There are parts of the process where there is really something creative [in science] . . . [artists] are much more free in playing around and exploring also the more subjective side of things and processes.

Material scientists immersed in their labs may be introduced to creative practitioners' soft knowledge insights into the user experience and 'real life outside the lab' (Niinimäki 2019).

Accepting disciplinary differences might build a more multifaceted picture of our world. Experiential knowledge-building between disciplines can open unexplored fields and questions or find emerging areas otherwise hidden (Figure 5). One scientist described the collaboration with an artist as 'mind opening'. Changing perspectives might help problem-solving and lead to unexpected results. As one interviewee said:

Figure 5. Scientists, designers and artists experiencing biomaterials drawing together in a workshop by Margherita Pevere. Photo by Margherita Pevere.

> Changing perspective is often the solution to a scientific problem you have. You have lots of data and it just does not make sense to you. Because you think about it in a certain way and it does not come together and you don't understand it. And then there is a process which has a lot to do with creativity. Basically, just change the perspective.

When we need multiple angles and perspectives towards problems that we are solving, collaboration between disciplines might offer the key if we do not concentrate on *how* we are building knowledge but instead focus on how these different epistemic perspectives could be *combined*. One scientist said: 'It's an illusion to think that objectivity exists. It's all influenced by the personality of the scientist'. This quote suggests that objectivity of scientific knowledge may leave room for personality or at least be contextualised. Instead of comparing or underestimating the different types of knowledge produced through different methods, approaches or 'languages', we need to find ways to combine these; from here we can begin to construct a genuinely transdisciplinary new understanding of the world.

However, the usually limited duration of funding challenges regular commitment to interdisciplinary research projects. The good intentions of an interdisciplinary approach are often forced into a multidisciplinary one in which the different disciplines work side by side, only combining the results of separate processes in the final article or prototype. Participants often think that their collaboration is inter- or transdisciplinary when in fact it turns out to be multidisciplinary (Refsum Jensenius 2016; Stember 1991; Zeisel 2006).

4.2. Collaboration challenges might become enablers

The discussion above shows factors that can lead to rewarding collaboration. Most of the interviewees clearly suggested that a lack of time working together or unwillingness to understand each other's language or an attitude of not being open for collaboration could negatively affect the research. These conditions might lead to miscommunication, feeble personal connection and trust, and no shared language on which to build or publish. Not acknowledging each other's work can generate frustration or distrust among collaborators. Some interviewees referred to further disrupting factors including stolen work, hidden agendas or difficult power relations as a source of distrust and consequent failure.

While these unfavourable conditions certainly set collaboration on the wrong track, we might also think of failure, disruption and miscommunication as opportunities for deeper reflection. Kahane (2017) suggests dealing with such instances by 'stretching' the collaboration and shifting away from the wish to control every part of the process or to change others in the team. Instead we could be willing to enter uncomfortable zones to embrace conflicts and move beyond them (2017, 42). This could enable open-minded experimentation with new possibilities, even though it may at first seem to go against what feels natural. Shared exploration, such as co-design processes, can push everyone's disciplinary creativity and boundaries forward (Niinimäki 2018). One encouraging example is the collaboration between a creative practitioner and a scientist in a botanic laboratory that led to a co-authored article on the sounds of fungi growing in soil (Rillig, Bonneval, and Lehmann 2019).

We found that transdisciplinary breakthroughs could emerge in spaces that nobody considered without having to stretch beyond their familiar discipline. Niinimäki, Tanttu, and Kohtala (2017) write that multidisciplinary collaboration in research on new

materials requires participants' readiness to step outside the practices of their discipline and learn collaboration. However, as the challenge to understand everything in several disciplines is overwhelming for anyone, Niinimäki et al. suggest that learning is not enough: a new type of knowledge intermediator is needed to bridge knowledge gaps between disciplines, so that shared understanding can happen (2017, 9), such as the idea of a T-shaped professional.

A common notion in the area of design, a T-shaped professional possesses deep domain-specific knowledge combined with the ability to apply this in a broader field to facilitate knowledge exchange between interdisciplinary collaborators (Karjalainen, Koria, and Salimäki 2009; Madhavan and Grover 1998). At their best, shared hands-on activities such as co-creation workshops can lead to cross-fertilisation, where 'scholars learn from each other, share methods of research and are willing to accept different interpretations of events' (Cross 2007, 99). Drawing on previous research (Niinimäki, Tanttu, and Kohtala 2017; Niinimäki 2018, 2019) and the valuable experience of our respondents, we embrace a daring approach to transdisciplinary research, and hope that it may contribute to paving the way for novel paradigms in research, beyond disciplinary thinking.

5. Conclusion

Based on our interview analysis, we would like to make a general note to researchers embarking on projects involving both science and creative practices. Trust and openness are key to communication in most contexts, but the specificity of interdisciplinary fields requires further care. Our respondents' experiences show how mutual understanding and the prerequisites for experiential knowledge transfer need to be built *consciously*, over a long period, by engaging in hands-on practices and cognitive activities that go beyond all the collaborators' individual comfort zones, while the common goals and research questions are motivating for all. Trust and respect need to be nurtured even when the ideas of collaborative partners feel unnatural or incomprehensible: breakthroughs may emerge because of these discrepancies. Such conscious development can contribute to establish and reinforce practices that help researchers to navigate unsettling zones between disciplinary boundaries.

While academic research funding agents encourage interdisciplinary research, the present research suggests that funding alone cannot motivate people to work together. Even when motivation and a common goal exist, the short duration of funding might push researchers to multitask: this is counteractive to transformational learning and knowing together. Thus, in addition to inviting enabling and open-minded T-shaped professionals we acknowledge the importance of conscious development in education (cf. Mejía et al. 2018). Curricula for interdisciplinary outlooks on arts and sciences can be established at universities which offer studies in multiple disciplines, as has already been implemented at some universities (cf. Royal College of Arts Global Innovation Design MA, and the University Wide Art Studies courses at Aalto University). Such educational approaches may slowly enhance the development of transdisciplinary knowledge to increase the possibilities for different disciplines to work together for more coherent problem-solving through 'soft' knowledge (qualitative approach; humanistic and creative) and 'hard' knowledge (quantitative approach; measuring and statistic). By appreciating and combining different epistemic approaches we can construct a multi-perspective understanding of the

world. However, such approaches also need academic acceptance, new ways of presenting scientific knowledge, and journals that are open for genuinely multifaceted views.

5.1. Limitations of the research

Interviewing a homogeneous group of researchers – for instance, only creative practitioners or only scientists, from one country or a single research area – could have provided comparable data on factors such as experience, internationality or research objectives. Instead we chose to look at qualitative aspects before comparative aspects. Additionally, a mixed author group including both scientists and creative practitioners may have resulted in a more comprehensive research outline and data analysis, including more of the scientists' views into the subject matter.

5.2. Future research

The formation of novel paradigms that combine the sciences, creative practices and humanities still allures research communities, and research is still needed on interdisciplinary processes that can generate models for best practices. Another aspect worth addressing is how funding might shape collaboration according to whether it is obtained by scientists or creative practitioners, and how this might affect power structures within the group or the continuity of the research.

Acknowledgments

We acknowledge the participants of this research, even though they cannot be named here, for taking time to talk to us. This research was supported by the Academy of Finland under Grant 307476 NEWSILK The New Road to Silk: Bio-based production of silk-like materials, the Kone Foundation and The Finnish National Agency for Education.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Koneen Säätiö; Finish national agency for education ; Academy of Finland [307476].

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