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DIMENSIONS OF MULTIDISCIPLINARY COLLABORATION: A COMPARATIVE LITERATURE REVIEW WITHIN DESIGN CONTEXT

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Abstract

In this paper, we review empirical studies of multidisciplinary collaboration in design and innovation activities. From 200 papers, we selected 17 for a meta-synthesis review. When revisited and compared, they present common themes and dichotomy in findings. This literature review discusses such diversity, offering a methodological critique of unclear areas. Four emerged themes were identified: (1) Knowledge diversity, (2) Trust, (3) Barrier and (4) Jargon and communication, providing perspectives for further research on how online collaboration will influence multidisciplinary team processes.

Keywords: multi-/cross-/trans-disciplinary approaches, teamwork, collaborative design

1. Introduction

Research has always seen creativity to be crucial for innovation, as it aids in problem solving. Design tasks are thus described as those solving complex problems and since creativity is argued to be a prerequisite for invention and innovation, it is considered to lead to the increase of market growth (Hewlett et al., 2013). It has been suggested in the report by McKinsey & Co (Sheppard et al., 2018) that there is a strong correlation between employing design practices and high business performance. The study shows that companies in the top quartile with MDI McKinsey Design Index scores have managed to increase their revenues by 32 per cent over the five years comparing to their competitors. This phenomenon appeared true in all three studied industries - medical technology, consumer goods, and retail banking. Following such findings, it has been underlined by the authors that design practices are applicable, and yet even beneficial for the development of physical goods, digital products and services, or a combination of these. Team collaboration discourse is undergoing a remarkable revolution as its virtual factor has become a widespread common practice in companies of all industries. At Alphabet\Google, another company from the top 5 most innovative ones, 100 000 employees are spread out over 150 cities from more than 50 countries. A company report (Gilrane, 2019) highlights that nearly half (48%) of meetings in Google involves employees working from different buildings, and 4 out of 10 meetings involve different cities. In the light of such event, there is now concern about how online presence is influencing the team process in multidisciplinary collaboration?

To date, design studies have evolved from the study of design practices to wide-ranging research of co-creation across various disciplines, including team communication and cross-cultural collaboration. The DTRS (Design Thinking Research Symposium) meetings started in 1991 with the research on design practices have developed into extensive researches on co-design and co-creation (Christensen et al.,

2017). A growing body of literature has examined multidisciplinary collaboration within the design and team contexts, yet, there has not been conducted a comparative review of such studies. To address that, this literature review paper investigates research articles from a meta-synthesis perspective (Robson and McCartan, 2016) and uses qualitative content analysis to identify key themes in the literature, while acknowledging the diversity of the findings and raising questions for further research. We follow the PRISMA guidelines, suggested by Moher et al. (2009) for the systematic review process used for the literature review. The selected research articles include a subset of 17 core literature studies from the period of 22 years (1996-2018), that has been chosen from the body of over 200 articles within the design context. Our selection focuses only on investigations, that employ a sample of multidisciplinary teams performing design tasks and those, that provide an overview of the empirical research within meso-scale team collaboration level (Cash et al., 2019). In doing so, this investigation contributes towards a better understanding of multidisciplinary design collaboration and how we can plan its future direction within online collaboration.

2. Defining multidisciplinary collaboration

Disciplinary background, in the discourse of design studies and the related fixation issue, influences the design processes. To overcome such fixation, many engineering firms integrate engineering, manufacturing, marketing, distribution and end-user knowledge together (Sonnenwald, 1996). First, it is important to define the scope of such approach in terms of disciplinary partnership. There is a division in the literature body of the meanings of multidisciplinary versus interdisciplinary versus transdisciplinary. All three levels of the disciplinary integration are defined by Adams et al. (2009) under one term of *cross-disciplinary* a practice, that includes:

1. multidisciplinary - joining together of disciplines to work on common problems and split apart when work is done,
2. interdisciplinary - joining together of disciplines to work or identify common problems and interaction may form new knowledge,
3. transdisciplinary - beyond interdisciplinary combinations to a new understanding of relationships between science and society.

For some, these terms should not be used interchangeably, as they describe different involvement degree of multiple disciplines in studied projects (Choi and Pak, 2006). Nonetheless, *multidisciplinary* and *interdisciplinary* have been used interchangeably by Kasali and Nersessian (2015) already in their abstract. This shows how, in reality, the barriers between such practices are being blurred in academic research. Therefore, for the purpose of this paper and to understand best practices for design collaboration, we cannot limit the review to only one of the layers of such collaboration. We will embrace both multidisciplinary and interdisciplinary terms together with cross-disciplinary collaboration in this literature review, in reference to complex problem-solving practices, employing many disciplines together, at all involvement level, defining the scope with an umbrella term of *multidisciplinary*. The next sections seek to methodologically analyse previous investigations and discuss findings from the research articles addressing this matter.

3. Variables manipulated in the studies

The past two decades witnessed a considerable rise of interest within the collaborative design paradigm. We present in the following summary table (see Table 1), methodological details of these research articles, with each row corresponding to one publication.

3.1. Research field

With an increasing need for domain-crossing collaboration, the issue of multidisciplinary teamwork has generated appeal among academic work. As presented in Table 1, out of the 17 core research articles, 8 studies were collected employing samples of university students. Albeit, the scientific community draws into attention extra caution with experiments on student samples, half of the investigated papers in this review are studies within the university context. Additionally, many of the industrial-based studies are

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laboratory experiments, where the authors have manipulated variables. This can become a limitation for validating the emerged findings. In the research world, experts do acknowledge this limitation and explain the choice of laboratory student teams plausible for the sake of methodological strictness (Stempfle and Badke-Schaub, 2002). They suggest that laboratory experiments can provide some insight into basic thinking processes and also, not being contaminated by unpredictable factors, which are prone to take place in research with an industrial context. Kasali and Nersessian (2015) notice, there has been little research into how interdisciplinary teams operate in the real world and how the multitude of professionals communicate and integrate their expertise. Only 3 studies in the core literature, were carried out in a natural setting, conducted in a non-experimental nature. Over 80% of the research articles involves experiments in a laboratory setting, highly correlated with the employment of student participants (60% of them with university context). A fundamental problem with studies created in such nature is that any generalisations to a broader population are considered hazardous (Robson and McCartan, 2016).

Table 1. List of core literature

First author, year	Experiment setting		Industry			
	natural	laboratory	construction	manufacturing	healthcare	software
Adams et al. (2009)	X		X			
Awomolo et al. (2017)		X	X			
D'Souza and Reza (2017)		X	X			
Feast (2012)		X	X			
Haines-Gadd et al. (2015)		X			X	
Hu et al. (2017)		X	?	?	?	
Jutraz and Zupancic (2017)		X	X			
Kasali and Nersessian (2015)		X	X		X	
Kleinsmann and Lugt (2007)		X	X			
Kleinsmann and Valkenburg (2008)	X		X			
Kokotovich and Dorst (2016)		X		X		
Mcdonnell (2009)		X	X			
D'Souza and Dastmalchi (2016)		X		X		
Sonnenwald (1996)	X		X			X
Steele et al. (2001)		X	X			
Wang et al. (2018)		X		X	X	X
Zolin et al. (2004)		X	X			

3.2. Industries

Multidisciplinary collaboration has gained popularity in the research society among all industries. The majority of studies in the core literature have been performed within the construction industry (see Table 1). We classify under this industry conjointly architecture, construction and engineering, and studies within such efforts engage over 70% of the analysed literature body. Most of the research papers, since they refer to design practices, focuses on architectural practices (Adams et al., 2009; D'Souza and Dastmalchi, 2016; Feast, 2012; Jutraz and Zupancic, 2017; Kasali and Nersessian, 2015; Mcdonnell, 2009; Sonnenwald, 1996; Steele et al., 2001; Zolin et al., 2004). Healthcare and manufacturing constitute 17% each of the literature body, suggesting why design practices and multidisciplinary collaboration can find their application in other industries, where creativity is in need. Similarly, only two studies include experiments that included software development (Sonnenwald, 1996; Wang et al.,

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2018). Overall, the studies indicate the increasing need to employ design practices into industries, previously considered as non-design practices. As mentioned in Section 1, applying lessons from design, result in monetary value to business. In the last decades, the economy has extensively switched to serviced industries and even companies producing hardware products, are alongside developing the most innovative digital applications to incorporate with their offering. The companies on BCG's most innovative list for 2019 (Ringel, 2019) — especially those in the top ten — extensively use Artificial Intelligence and platforms for digital products. According to literature, participants from the software department or any mechanical-oriented divisions create barriers in the multidisciplinary collaboration as they employ different development processes while using different jargon and different representations of the design (Kleinsmann and Valkenburg, 2008). On the contrary, architects can draw on their experiences from design nature, and act as enablers for efficient collaboration, setting out the right processes (Mcdonnell, 2009) and mediators between varying professionals (Jutraz and Zupancic, 2017). As a result, the disciplinary background of participants seems to directly impact the results of the experiments and research has been equivocal in terms of generalisation of findings on multidisciplinary collaboration.

3.3. Design process

As with the disciplinary background of the participants, the literature body varies in the examination of the participants' work type and the design process itself. In most of the studies, the participants are being instructed to focus on developing a physical product, e.g. buildings, backpack, car accessory for industrial or product design objective. In one study, Hu et al. (2017) investigate how can the mindset of participants switch from industrial thinking to service thinking. They find that the mindset shifting process is significantly influenced by communication and interactions between the participants. Moreover, in order to successfully cope with service thinking without previous experience in this domain, participants are required to present frequent knowledge sharing. In a similar fashion, Kokotovich and Dorst (2016) study how designers can move from traditional concepts towards a higher level of abstraction. Their investigation, that resulted in a website for the cards industry (digital product), suggests that multidisciplinary teams have difficulties in crossing domains and could not develop higher levels of abstractions. Bearing that in mind, 65% of the design outcomes are physical products, and in only 3 scenarios the resulting product is digital (D'Souza and Dastmalchi, 2016; Kokotovich and Dorst, 2016; Wang et al., 2018). Considering these studies, the discourse of multidisciplinary collaboration raises limited understanding of issues related to the nature of digital outcomes and the high level of abstraction. In addition to design objective and outcomes, variables concerning the design process itself vary across the core literature. The majority of experiments refer to conceptual work, but only 3 studies include the prototyping phase. However, it was found by Haines-Gadd et al. (2015) that prototyping is instrumental in the design process by decreasing mistakes and improving the design. Moreover, they suggest further that prototyping can be utilised as tools for communication and integration between the participants. The idea is supported by the research of Kasali and Nersessian (2015), who find that prototypes are critical in bringing together the differentiated expertise within the multidisciplinary teams. Overall, it seems important to include prototyping in projects involving participants from different disciplines. Moreover, multidisciplinary teams seem to be challenged when conducting projects requiring a higher level of abstraction or developing digital products. As noted, it is not clear how emerging issues can be mitigated.

3.4. Team characteristics

On an individual level, team composition related characteristics are other manipulated variables studied by the authors. Although many studies emphasise the importance of leadership in group work, the role of a project leader tends to be interpreted differently in the literature. Sonnenwald (1996) suggests as one of the responsibilities of such a team leader to include filtering and sharing information about the project's goals, plans, tasks, and detailed budget information. Consistent to this point, Kleinsmann and Lugt (2007) describe the project leader's tasks to be planning and monitoring the design process and the costs. An important aspect of leadership is that while guiding the group through the design activity, there is a risk of the team leader progressing without agreeing the project's direction with the remaining participants (Steele et al., 2001). Therefore, the leader often takes another

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role. As Awomolo et al. (2017) find in their investigation, that the team leader makes the most of the design decisions concerning not only the methodology used in the meeting but also its content. They suggest that by having multidisciplinary participants, such dominance level of the team leader can be reduced. A further approach on a leadership role is presented by Kleinsmann and Valkenburg (2008), in another experiment, where they find that the team, who shared leadership roles, resulted in the best design outcome. Another study of Haines-Gadd et al. (2015) presents the idea of the leadership role rotation, that becomes an enabler for new collaboration energies to take place at various project stages. Feast (2012) suggests, that team size will also affect the collaborative level of the group. One person can easier influence the small team, whereas, in larger teams, the more distributed workload results in lesser ownership from an individual. Wang et al. (2018) recommend the team of 6 participants in order to distribute the expertise within a multidisciplinary team evenly. Overall, team characteristics, including its size and leadership, play a great role in multidisciplinary collaboration, making a considerable impact on the team spirit.

4. Emerged themes

We collected the bibliometric data with abstract content of the core literature from Scopus to construct and visualise the co-occurrence network of emerged themes. To perform the text mining functionality and create the term map (see Figure 1), we use VOSViewer (Van Eck and Waltman, 2011) that employs *natural language processing* algorithms to identify relevant terms. In order to unclutter the representation, only the co-occurrences with a frequency of more than twice were included in this analysis. For each theme, the size of the label circle and its font size mirror the importance of such theme, and the varying colours represent classification clusters. These clusters lead to four identified themes that are in line with our content analysis.

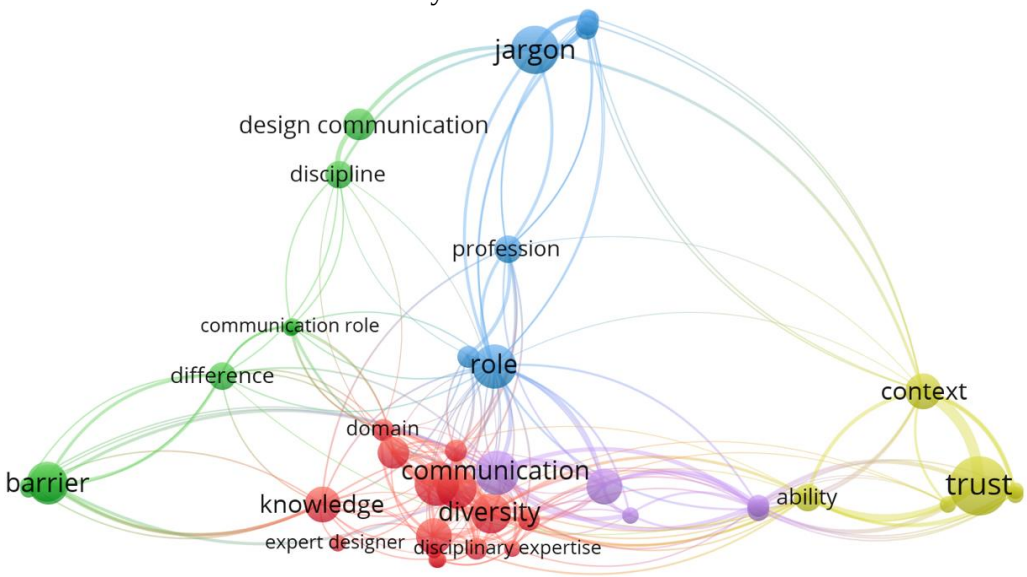

Figure 1. The co-occurrence map of emerged themes

4.1. Knowledge diversity

In all studies, authors define studied teams as multidisciplinary or interdisciplinary. However, one could notice that many of them were homogeneously creative-industry characterised; for example, they were arranged with designers or design-related professionals. Albeit, Awomolo et al. (2017) highlights that having multiple functional groups reduces the impact of roles and positions on decisions (leading to a more interactive and democratic approach), their sample comes from the DTRS11 workshop where 5 out of 8 team members belong to the Design Team, and the other 3 External Consultants were Market researcher, Design researcher and Design Thinking expert. This leads to the conclusion that almost all participants have a similar background under the design umbrella, apart from the one market researcher. Kokotovich and Dorst (2016) notice that design teams consisting solely of designers, in general, have

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very similar perspectives and heuristics. Therefore, their sample consisting of a group of designers and non-designers is supposed to tackle this homogeneity. Unfortunately, when investigating specialisations of each team member, we can enlist art drawing, painting, architecture, storytelling, art photography, journalism, graphic design or psychology. According to the definition from the American National Endowment for the Arts – the arts term includes (U.S. Congress, 1988):

> *"music (instrumental and vocal), dance, drama, folk art, creative writing, architecture and allied fields, painting, sculpture, photography, graphic and craft arts, industrial design, costume and fashion design, motion pictures, television, radio, film, video, tape and sound recording,.."*

Similarly, the team of participants coming from art, architecture, psychology, journalism and English in the research of D'Souza and Dastmalchi (2016) described by the authors as a multidisciplinary team, is *de facto* homogeneous, as all disciplines are already requiring a high level of creativity or strongly related to creativity study - including psychology. Another study from Kleinsmann and Lugt (2007) analysing the collaboration between multidisciplinary participants, is designed with the simulation of chosen skill sets. Notwithstanding, all participants have been recruited from design bachelor and master students and professionals with design experience. The laboratory study, albeit with simulated multidisciplinary role-playing, would still be heavily biased due to homogeneous designers' perspectives of all team members. Similarly, the sample from the study of Hu et al. (2017), defined as multidisciplinary, employ graduate students from Industrial Design, Visual Communication Design, Furniture Design and Mechanical Design, Automation - the majority of which is still within the design discipline. One of the most common instances, where multidisciplinary collaboration is inevitable, occur when the end-user is involved. They also bring expertise from their disciplines (Adams et al., 2009; Feast, 2012; Mcdonnell, 2009; Sonnenwald, 1996). Adams et al. (2009) involve in their study experts with a minimum of fifteen years of experience: including architects and designers and end-user professionals such as doctors, nurses, engineers or hospital managers. Sonnenwald (1996) in her field study within the software design analyses the communication between software engineers, software designers and end-users, who were salespeople, sales managers and client's office staff. She presents the communication roles that emerged during the design process and enabled the team to integrate multidisciplinary knowledge and form boundary-spanning activities collectively. Mcdonnell (2009) looks into the conversations between the architects and the building users, in which she discovers blurred boundaries between the participants' argumentation. Such phenomenon defines the collaborative negotiation between parties where an expert expression revokes a new expert response. This is showing how the design shared ownership is created within the multidisciplinary team through social interactions and recognition of one's role and expertise. Similarly, Jutraz and Zupancic (2017) suggest that the roles for users and experts are overlapping in meetings. In their study, user roles are represented by participants with expert practitioners in healthcare, such as hospital emergency department director. They argue, hence, to consider these participants as another domain experts.

According to Kokotovich and Dorst (2016), novices cannot cross domains nor develop new higher levels of abstractions. Their sample of the least experienced participants was represented by students from the undergraduate academic level. In 56% of the observed instances, the team was not operating on the *competent level* (Dreyfus, 2004), where problem-solving is accompanied with high design situation involvement, emotional involvement, learning and reflection. Contrary to this, D'Souza and Dastmalchi (2016) find that undergraduate juniors still make a significant impact on the design process. However, in the study of Kokotovich and Dorst (2016), the novice team did not use any methodologies or tools, and thus did no enrich the solutions space. Lower experience level, in the research of Haines-Gadd et al. (2015), led to inefficient use of time and resources. In the majority of studies, teams are being formed in a laboratory experimental way with students from the same academic year. Notwithstanding, in a real-world situation, there will be a diversity of experience level across the project team, ranging from 0 to over 30 years. An interesting perspective is presented by Sonnenwald (1996), where she suggests that the number of years of professional experience reflects the participant's role within the group. For example, participants with minimal professional experience can take on the roles of facilitation interaction between members within the project. Participants managing cross-organisational information require

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more than 8 years of professional experience, with these coordinating activities with more than 14 years. It is worth highlighting that the interdisciplinary star who integrates knowledge from different disciplines and domains has a minimum of 10 years of professional experience.

4.2. Trust

A study of Haines-Gadd et al. (2015) highlights the importance of trust in multidisciplinary collaboration. Similarly, from the investigation of Zolin et al. (2004), trust is found to be a critical component in cross-functional teamwork. Apart from varying domain-related perspectives and regional/ national cultures, geographical distribution (and resulting lack of *face-to-face* interaction) plays a great role in decreasing the level of trustworthiness between participants. In terms of disciplinary background, respondents from their research, claim that they would trust professionals from the same domain more than from other professions. Consistent with this, broader literature body supports such finding that direct, in-person meetings increase the trust between participating members, which results in higher creativity and quality of the work (Gloor et al., 2012). Even without the respect of disciplinary background, Feast (2012) reveals that bringing an outsider to an existing group, where participants' roles have been established, creates distrust and further misunderstanding of the group's motivations. Summing up, in order to efficiently collaborate with team members from the different disciplinary background, a high level of trustworthiness is required. This becomes considerably challenging in the light of barriers resulting from varying domain-related knowledge, cultural diversity, language used and potential geographical distribution.

4.3. Barrier

Apart from expertise, intrinsic motivations and personality are other components of creativity (Amabile, 1988). Personality characteristics provide independence, ideas generating skills and enable taking new perspectives on the problem. However, group cohesion is affected by motivations, world views, egos and clashing personalities (Goldschmidt, 1995). This is supported by the investigation of Steele et al. (2001), in which they suggest that the lack of group cohesion and confrontational attitudes are challenged with differing personalities. Feast (2012) highlights that such conflicts influence the teamwork so much, as it can lead to one-sided collaboration, when a participant's ego is being intimidated or when she/he receives less responsibility than expected. Another aspect of bridging disciplinary barriers is knowledge convergence that enables mutual agreements between participants to take place and create shared understanding (Feast, 2012). This has also been emphasised in the study of Hu et al. (2017), who suggest that more frequent knowledge sharing behaviour together with the complex sharing network lead to faster mindset shifting from one discipline to another. Mcdonnell (2009) defines shared understanding to be created through conversation during the design negotiations. Such exchange allows experts to express their non-expert knowledge, which in turn invites the end user to draw on their expert knowledge and thus gain a better understanding of the design context. Moreover, Kleinsmann and Valkenburg (2008) find that shared understanding is dependent on the *face-to-face* team communication, project management and project organisation.

In our core literature, visual representations emerge as both facilitating and bridging medium between disciplinary boundaries. Adams et al. (2009) state that non-verbal activities, including gestures and drawings, act as communication between the group members, supporting multidisciplinary collaboration. They manage to build on each other's ideas in the forms of such visual representational practices. Consistent with this, Kasali and Nersessian (2015) suggest that design drawings are critical in developing cross-domain expertise. Such drawings are thus defined as a synthesis of multidisciplinary knowledge. They suggest that beyond the verbal interaction, these visual representations act as a key role in translating and blending differing professional expertise. This enables multidisciplinary assessment in the group, leading to later consensus among the participants. Mcdonnell (2009) highlights that the visual representations play an important role in defining the routine for internal interactions, helping to organise the discussions' themes. However, quick sketches in order to act as a bridging medium, require already established shared understanding in the collaboration (Feast, 2012). Similarly, a study from Kleinsmann and Valkenburg (2008) supports this finding, when an electrical engineer created an explanatory drawing for the ergonomist. However, they were still not able to productively negotiate with one another a solution

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to the problem. Kleinsmann and Lugt (2007) in a different study, suggest that the correct perception of the sketches requires knowledge of the jargon and an understanding of the context.
On the whole, participants from different disciplines use different methods to represent the design context and additionally use different jargon and different levels of abstraction. All these seem to affect team level of shared understanding, required to overcome disciplinary and personal barriers.

4.4. Jargon and communication

As design is defined as a social process (Bucciarelli and Bucciarelli, 1994), it is crucial to make efforts investigating the communication within it. This has been quantified by Steele et al. (2001), who observe that social interaction is a critical component and accounts for 21% of the conceptual design activity time. They also notice that social interaction is neglected in the used framework model. Additionally, renegotiation of the earlier defined roles of the team members emerges as a feature of social integration during the design talks (Mcdonnell, 2009). Sonnenwald (1996) suggests that any interpersonal talks, e.g. about weather, families or hobbies facilitate the discovery of other participants perspectives and language, which can lead to establishing personal bonds. Kleinsmann and Valkenburg (2008) suggest that on the team communication level, the difficulties emerge due to differences of jargon used by the participants, different design representations and responsibilities. Similarly, the importance of understanding the communication and design jargon issues was advocated by D'Souza and Reza (2017). Hu et al. (2017) define different jargon as unique, specialised work languages together with different past experiences, work patterns, quality and success perception, organisational priorities, and technical constraints. High constructive interactions foster productive creation of good ideas, promote idea integration and co-building. One person contributes from his/her discipline expertise, inviting the other to respond and supply information with the provoked expert response (Mcdonnell, 2009). This, however, requires the recognition of others expertise and appropriately timed assertion of such expertise in order to reach consensus. Jutraz and Zupancic (2017) observe national-specific characteristics as other communication obstacles. Participants from Asia are described as quiet, polite and less impulsive than those coming from Europe. This leads to different communication styles between these cultures, as the Asians would not express their opinion and mainly listen to others. At the beginning of the meeting, discussions would only take place among the European participants. As a result, respondents from the study, point out that it is not the work with different professions, but working with different cultures and characters is more challenging for them. Zolin et al. (2004) find that such cultural differences result in varying expectations, lower predictability, and following the decrease of the trust level. They suggest that the underlying rationale for this can be cultural misunderstandings instead of potential prejudices. In a similar study of meetings, including Asian - European collaboration, D'Souza and Reza (2017) take on the investigation of language within the cross-cultural design process. Their analysis of jargon/slangs used by Eastern and Western participants reveals the different characteristics between these two groups, in terms of their individual *vs* collective and expressive *vs* restrained perspectives. They also point out the presence of cultural brokers in the sample and raises a question on how the design process can overcome barriers from cross-cultural jargon in the absence of such translators. Considering these aspects, the differing jargon use in multidisciplinary design meetings relates to their disciplinary diversity and cultural background. Social interaction and frequent constructive interactions can facilitate resolving possible communication tensions.

5. Discussion

As presented in previous sections, research efforts to date provide many lessons on multidisciplinary collaboration in design engineering activities. Albeit the studies have been performed comparably, there are differences in findings among variables related to the experiments. This leads to a conclusion that there is still room for interpretation and further discussion of conclusions from the studied core literature. Among the emerged themes, we can identify prominent areas worth taking a closer look. Communication and social integration lie in the heart of team collaboration. Conflicts regarding these aspects are related to personalities and perspective variation of the participants and jargons used by them. It seems that misunderstandings are common in multidisciplinary teams, which is also magnified by the differences in cultural background, and geographical distribution of the team members. Visual representations appear to be a good bridging medium and facilitator for potential conflicts. However,

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there is a requirement of an established shared understanding between participants. In the recent study of Cash et al. (2019), knowledge sharing actions were 4 times more frequent in the multidisciplinary team comparing to the monodisciplinary one. As design approaches are now challenged in innovation development with globally distributed teams (Section 1), the findings leave room to debate on how such teams can stay creative in an online environment? Moreover, as project outputs become digital on service platforms, what are the boundary-spanning communication aspects that can help distributed teams deliver these outcomes. Research in other areas can bring good inspiration for future studies on applying such approaches from multidisciplinary collaboration on a wider scale. An attempt in the analysis of non-physical meetings by Wasiak et al. (2010) refers to the use of *content analysis* of participants' email conversations. This can be a starting point, where one can look into how online collaboration should be investigated. We can also identify one of the methodologies, already used in (homogeneous) design collaboration research, *latent semantic analysis* of intra-group communication proposed by (Dong, 2005). Moreover, Sonnenwald (1996) already two decades ago suggested *social network analysis* as an idea to identify patterns of communication behaviour and the relationship of such patterns. Such approach can be recreated by performing *dynamic semantic social network analysis* (Zhang et al., 2013). Considering both important aspects from this literature review - communication issues with varying jargons and the potential of visual representation as an integrating medium - one promising approach involves *natural language processing* (NLP). The most recent research effort from Yang et al. (2019) presents attempts to create a rapid, NLP-powered sketching tool to enhance writing experience during design activities. They present yet challenges that still need to be addressed in further investigations and raise questions on how their findings can be generalised to other design situations.

6. Conclusion

Research into multidisciplinary collaboration from design studies has excellent potential to provide insights into teamwork. However, due to variation in variables used by the experiments' authors, findings include both common similarities and contradictions in some aspects. We analysed such differentiation and identified emerging key themes, which can become a foundation for future research. Reviewing current literature body on multidisciplinary collaboration is an important starting point in defining how to examine teamwork and develop tools for collaboration in the realms of the current innovation-led economy.

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