Investigating the Significance of Informal Interactions within Interdisciplinary Design Activity

Feast, Luke Edward Eric

Published in:
Consilience and Innovation in Design' IASDR 2013

Publication date:
2013

Document Version
Publisher's PDF, also known as Version of record

Investigating the significance of informal interactions within interdisciplinary design activity

Luke Feast*
** Swinburne University of Technology, lfeast@swin.edu.au*

Abstract: Designing is an activity that integrates knowledge from many different domains to create something new or to solve a problem. However, the innovative power that interdisciplinary approaches bring adds an additional layer of complexity. Additional factors come into play when stakeholders with specialist skills and diverse worldviews must create shared understanding to meet high-level goals. The paper presents results from an empirical study of interdisciplinary collaborative design activity in industry. Ethnographic case studies of three companies were conducted and twenty-seven (n=27) semi-structured interviews were recorded. The study used the DRM approach (Blessing and Chakrabarti, 2009) and using NVivo CAQDAS software supported theory construction. I identified twenty influencing factors and illustrated their dynamic interaction within a model of the collaborative design process. The study found that the innovative power of interdisciplinary collaborative design is underpinned by informal interactions. Consequently, I argue that developing design methods should take into account the significant role that informal interactions play within interdisciplinary collaborative design activity.

Key words: Design Activity, Design Methodology, Case Study in Industry, Interdisciplinarity

1. Introduction

Design research has made advances that have improved understanding of the nature of design activity. Building existing knowledge reveals new avenues for research to meet current challenges. While design research has been successful in developing systematic design methods for well defined design problems, the design process during the initial design phases are unstructured and few existing design methods are useful. In these circumstances, factors such as organisational culture and collaboration affect project success just as much as hard engineering methods [1]. Moreover, although the capacities of some individual designers may be impressive, the scope of knowledge required to understand all aspects of complex problems are often beyond the cognitive limits of a single person, making it necessary for all involved stakeholders to participate, communicate, and collaborate [2, 3]. Collaboration in interdisciplinary teams is a way to bring a broad set of perspectives to bear on a problem before stakeholders make key project decisions [4, 5]. Stakeholders work collectively through integrating their experiences and technical knowledge to meet complex problems [6-10].

2. Design Research Methodology

Research concerning the nature of collaborative activity has been the concern of various independent research traditions within a number of different academic disciplines, for example; knowledge management [11, 12] and cognitive science [13, 14]. This research project sits within the discipline of design and the research tradition of design methodology [15, 16]. Broadly, design methodology is the philosophy of science applied to practical disciplines [17]. In this sense, the aim of design methodology is to single out the activities and operations performed by designers when they act qua designers and state clear definitions of those activities [18]. The premise of this tradition is that we need to understand what designers do to develop support for design activity. Together these two aspects achieve the overall aim to make the design process more effective and efficient, in order to allow design firms to develop more successful products [19].

There has been on-going research within design methodology concerning collaborative design activity, however, aspects of this stream of inquiry remain under researched. Design methodology has frequently utilised laboratory based observation and protocol analysis techniques to study design activity [20]. While protocol analysis is a valuable research method, it has limitations for studying collaborative design activity due to the reality of the types of problems that are able to be solved within a laboratory environment within a few hours [21]. Recently, ethnographic techniques have emerged as practical approaches to studying the complexity of professional collaborative design work in industry [1, 2, 5, 10, 22-25]. Studies such as these provide insight into the complex combinations of interacting activities of people working together, which complements the knowledge developed through other research methods. This study aims to build on research concerning social processes in design activity through exploring professional designers' experiences of working in interdisciplinary collaborative teams.

This study takes the realist ontological position that a theory should do more than tell us about observable regularities, rather it should tell us about what sorts of mechanisms, processes, etc. exist, and the relations between them [26]. The realist search for explanations is the search for systematic factors operating in the world. A theory illustrates the relationship between factors and predicts what happens when they interact. Accurate prediction is convincing evidence in favour of a theory. Furthermore, causal relations are irreducible features of the world that we can learn about through empirical research. The choice between competing theories can be based on their explanatory power. When a theory introduced to explain one phenomenon, explains another independent phenomenon that is evidence that it is an accurate description of the world. The best explanation of a theory's success is that the mechanisms and events that it postulates actually exist or closely resemble what actually exists.

This study uses the DRM Design Research Methodology approach developed by Blessing and Chakrabarti [19]. The DRM approach is consistent with the realist ontological position and presents a methodology that aims to develop theory about design activity and validate support founded on those theories.

2.1 Description of sample and data collection methods

The data collection process started with a pilot study that involved interviewing professional designers. I used an open sampling approach to maximize variations in respondents' experiences and perspectives by approaching designers with different disciplinary backgrounds and professional experiences. I conducted semi-structured in-context interviews with twenty-seven (n=27) respondents over a nine-month period. The average duration of the interviews was one hour, with their length ranging from 45 minutes to two hours. I asked the interviewees to describe and reflect upon their professional work experiences. I structured the interviews around a common set of questions concerning sensitising concepts regarding collaborative design work. As key issues arose, I generated further detail of respondents' understandings through a flexible and unstructured approach utilising probing and follow-up questions. I used this semi-structured approach to create a sense of reciprocity and explore the complexity of the topic as the interview progressed [27]. I recorded the interviews using a digital recording device, and took supplementary notes during the interviews. I transcribed the interviews as soon as possible after I recorded them and recorded memos of my immediate impressions, ideas, and theoretical reflections. All the interviews from this pilot study are classified with the title 'Case 4: Pilot Study'.

The second stage of the study investigated designers from three different professions in their naturalistic environment through the observation of their approaches to collaboration. The observations focussed on the initial stages of the design process. I took the participant-as-observer role and made the fact that I was an observer clear to the groups from the start. I observed and tracked the activities of the designers by taking notes, collecting visual material, participating in design activities, and asking questions to explain various aspects of the activity as it unfolded [28].

The first case study concerned the collaboration between a large government department of conservation and a small industrial design company. Three senior industrial designers and one junior designer worked in the company, which produced biodiversity management devices. I immersed myself with the designers and observed their everyday work. I observed the parallel development of projects from initial concept development to redesigning existing devices. Furthermore, I participated in testing prototype devices in remote environments with the designers and research and development staff from the government conservation department.

I conducted the second case study within a small architectural practice of two senior architects and two junior architects. The architectural practice specialised in residential design and emphasised the design of architecture as both building and a form of cultural production. Here, I observed the architects' everyday work in their design studio from the early stage conceptual design until the presentation of the developed design to clients.

The third case study was at a large market research agency. I embedded myself within a qualitative research team comprising of three senior researchers and six junior researchers. The team I followed had specialist experience in conducting design research for large multi-national consumer electronics companies. I observed the everyday work of the researchers and followed several projects concerning design research for interaction design, information design and service design projects.

I processed the resultant observation field notes and interview transcripts and entered them into NVivo computer-assisted qualitative data analysis software. Data collection and analysis proceeded concurrently until I reached theoretical saturation [29].

2.2 Data analysis

Semi-structured interview and participant observation are methods well suited to studying real-world design activity because of their flexibility to deal with complex situations. However, as with all data collection methods, they are subject to forms of bias. One significant source of bias is the fact that the researcher is the instrument that collects data. Bias may be introduced through selective attention because the researcher observes some aspects at the expense of others. Moreover, the researcher's expectations might affect what he or she records. Furthermore, leaving time between the observation and theory construction means that the researcher may only recall particular aspects. In addition, interpersonal factors such as age, gender, experience may lead the researcher to focus on certain members of the group, which effects their picture of the whole group. However, while these biases cannot be eliminated, I accounted for their effects through triangulating the findings across multiple data sources and through observing multiple cases [28, 30].

Triangulation uses several methods at once so that the biases of any one method might be cancelled out by those of others [30]. Because triangulation integrates multiple perspectives it enhances the quality of research projects characterized by different viewpoints [30]. In this study, I used methodological triangulation by utilising semi-structured interviews and participant observation, and data triangulation through observing multiple cases. However, it should be noted that I use data triangulation to build findings from one case upon another case rather than to produce true statistical generalisation. The multi-case approach does not attempt to produce replication of the phenomena under study in the experimental sense of natural science research, but it does aim to increase coherence and depth.

I used the constant comparative method to uncover influencing factors within the data. Constant comparative method compares all emerging codes, categories and concepts to explore variations, similarities and differences [29]. I created a model of influencing factors (Fig 1.) as the basis of theory construction. Following Friedman [31]:

> Theory can be described in many ways. In its most basic form, a theory is a model. It is an illustration describing how something works by showing its elements in their dynamic relationship to one another. The dynamic demonstration of working elements in action as part of a structure distinguishes a theoretical model from a simple taxonomy or catalogue. A theory predicts what will happen when elements interact.

The model integrates the analytic themes, the insights from the case studies and concepts from the literature, to map the network of influencing factors that affect interdisciplinary collaborative design activity. Theory is grounded in the respondents' experiences so that the reader can make connections between influencing factors and the data from which they came. The following section presents the model of the insights from twenty influencing factors along with extracts from the data.

3. Modelling Interdisciplinary Collaborative Design Activity

The following model (fig. 1) illustrates the interaction of twenty factors within the collaborative design process. The factors influence the design process through seven stages starting from the complexity of the design problem, through the design activity of the collaborative team and culminating with the contribution to culture.

The first stage shows the formation of a diverse design team in response to the degree of complexity of the problem. Second, the stakeholders need significant time to develop of shared understanding of the problem. Third, iterative prototype testing develops designs. Fourth, supporting the continuity of the design development takes care because the parameters of the problem are uncertain and changing. Fifth, social factors and group cohesion affect the team's ability to attain a common goal. Sixth, through the process of synchronising their knowledge the team members can learn from one another. These stages all contribute to the team's capacity to meet high-level goals and contribute to culture. The following sections describe each factor and explain their patterns of interaction.

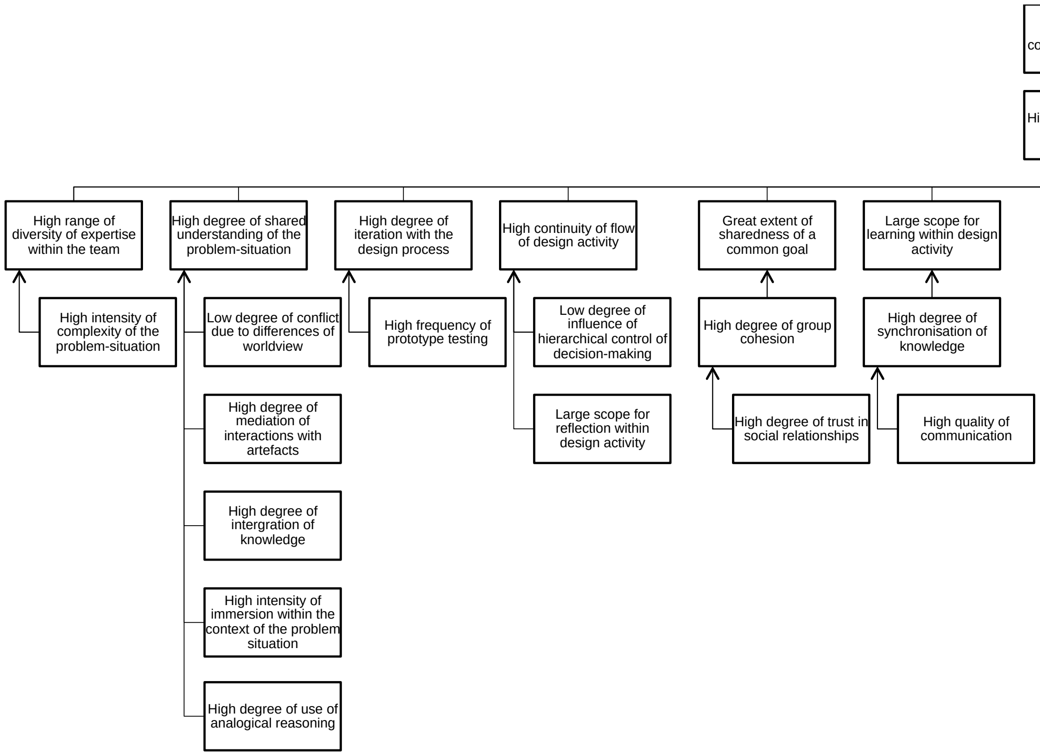

Figure 1: Model of factors influencing collaborative design activity

3.1 Complex problems, diverse expertise

Design teams work to solve a problem or create something new. Sometimes the focus of their activities is on relatively mundane and well defined problems, at other times the team confronts situations where simply figuring out the nature of the problem is "the problem". In situations where the design team must work to solve highly complex problems, a first stage is to organise a team comprising of stakeholders with a high range of diversity of skills and backgrounds. As Nathan, a senior strategic and organisational designer describes:

> When you are dealing with complex systems, um, the one thing you have to kind of come to grips with early on is no one's got it, no can see enough, know enough, understand enough, to wrap their brain around it, you need multiple perspectives, you need multiple disciplines. (Nathan, Case 4: Pilot Study, Code 1.1)

First, complexity is caused by the interrelationship and intricacy of the problem's elements and functions, and second, due to the social, cultural and organisational context of its stakeholders. The complexity of the problem may mean that the scope of knowledge required to grasp all aspects of the problem is beyond the cognitive limits of a single designer. Consequently, designers must integrate knowledge from different disciplines and specialisations. Through utilizing diverse approaches, perspectives, or specialist expertise, the team can generate a larger "thinking footprint" needed to identify more opportunities and weaknesses. Moreover, by taking advantage of the strongest capabilities of all stakeholders, the team can innovate at different levels and with greater detail, generate greater variety of ideas and uncover tacit aspects of the problem.

3.2 Developing shared understanding

The breadth and depth of expertise that a diverse team brings also adds the need to construct shared understanding of the problem. Five factors support the team to develop shared understanding: high use of analogical reasoning; high immersion in the context; high integration of knowledge; high use of artefacts as mediators; and low conflict due to differences of worldview. Taking into account these different factors allows the team to develop a more comprehensive solution. As James, an industrial designer, describes:

> [We] could have just done it from a design point of view and made it pretty and functional and that's it. But we did it from an ecological point of view, a design point of view, a financial point of view, a customer point of view, that's why it makes sense, people understand it. (James, Case 1: Industrial Design, Code 1.3)

There are prescriptive and interpretive approaches to developing shared understanding within collaborative design activity. Prescriptive approaches involve capturing and structuring team members' communication within a common language to coordinate decision-making processes within the project timeline. Interpretive approaches develop a localized sense of shared understanding through team members' conversations and interactions that strengthen understanding of stakeholders' practical, social, and psychological needs.

When designers immerse themselves in the context they witness how issues unfold, understand the day-to-day lives of the problem owners and share experiences with stakeholders. Direct experience of the context is a powerful means for designers to understand what people do, what they value and how they understand things. Moreover, immersion supports stakeholders to challenge their assumptions and provides meaning and a reference to insights.

Through accessing expert knowledge and experience, the team should be able to integrate facts, theories, principles, or techniques that fall outside the design discipline. Consequently, they can increase the degree of innovation and number of alternative ideas produced. In addition, integrating knowledge from diverse disciplines may require the creation of new or modified approaches that mean that stakeholders must work within unfamiliar fields.

Stakeholders bring together knowledge from different contexts to bear on the problem at hand in a form of analogical reasoning aimed at starting a conversation to lead on to something else. For example, stakeholders may introduce existing technologies, processes, personal experiences, or simulated scenarios of use as evidence within discussions. Analogy is a beneficial strategy for integrating knowledge and maintaining concept development when faced with the uncertainty.

Creating drawings and models can involve both interactively constructing ideas with others or refining one's own thinking. Furthermore, representation techniques can be used to record and synthesise ideas during discussions, which aids the development of shared understanding of the problem. In addition, designers and stakeholders use artefacts as co-design tools to gain insight and empathy.

However, the innovation that diverse expertise brings can also lead to conflicts due to differences in worldview. Differences of worldview may become manifest in terms of opposing cognitive procedures for solving problems, in social relationships regarding organisational cultures or personality clashes, or in misunderstanding due to jargon-laden communication. These differences can develop into prejudices that cause stakeholders to be disrespectful to other's contributions. Working through differences in worldview and meaning is an essential aspect of developing shared understanding of the problem within the team.

3.3 Iterative prototype testing

Utilising 2d and 3d prototypes within design activity is an influential factor in interdisciplinary collaboration. The role of prototyping is to generate evidence and test ideas rather than as a "brainstorming" technique. In this sense, prototyping is an evolutionary process used to develop, evaluate and refine designs into final systems. Consequently, in collaborative design processes where there is a high frequency of prototype testing, there is also a high degree of iteration. As Max, an industrial designer, describes:

> [We] tend to make things as soon as we have an understanding of what it is. Soon as we have an understanding of how it might work we immediately go and make it and trial it, make it and put it in the [field]… Because you can sit around and guess it, you can think about, you can make assumptions about how things might work but in the end you can only put it in the field and test it to prove it. And that is where everything has to be proven. So model making is sort of a funny thing I guess in terms of, I mean, a model is a working functioning thing around here… so we make the object but it has to perform and function in the environment. So it can be kind of limited in a way you know, because we can't just make a cardboard model because it will never withstand the environment, also we can't just print it out because the print out can't withstand the physical rigours. (Max, Case 1: Industrial Design, Code 2.1)

The specifications of different components in complex products systems are dynamically interrelated, and changes to one component affect the performance of the other components and the overall success of the device. Thus, prototyping is a technique for managing design development where parameters and specifications are both highly interrelated and constantly changing. Iteration forms part of the design process that tests and refines prototypes in a cycle. The process evolves prototypes through testing designs and explores possibilities in response to the results of experiments, changes in specification or in light of new knowledge and so on. Highly iterative approaches work more like "conversations" between stakeholders where one idea prompts another. This approach enables the design to cross disciplinary boundaries as well as develop greater detail and meet high-level goals.

3.4 Maintaining Continuity of design activity

Because interdisciplinary collaboration deals with greater complexity, it requires greater understanding, more iteration and involves a greater degree of uncertainty. Design activity must take care to maintain continuity because high uncertainty can cause breakdowns in the flow of activity. Managing the impact of hierarchy on decision making and allowing opportunities for reflection, supports the design team to keep the development of ideas progressing. As Mark, a senior industrial designer describes:

> I think it's true you do feel the flow sometimes, and actually that's what experienced people at [company] learn is that, and slowly get more and more comfortable with, is that whole uncertainty. (Mark, Case 4: Pilot Study, Code 3.4)

Stakeholders employ subtle social strategies aimed at maintaining the flow of the team's collaborative interactions. Group design activity involves using tentative language and bracketing disagreement to keep the conversation going and to explore the implications of stakeholders' responses. These strategies maintain the flow of interactions to encourage fresh ideas, deal with uncertainty under pressure and investigate unexpected alternatives as they arise. A design conversation becomes a constructed meaningful interaction through the stakeholders' outward interactions and their inner self-reflexivity when adjusting their responses to each other. At the end of design phases, reflection is a critical activity where stakeholders can evaluate unexpected issues and solutions, and consider how current solutions compare with previous experiences.

Stakeholders' participation within collaborative design activity can be influenced by their position in the group's hierarchy and their job roles. Sometimes stakeholders may use their influence in the hierarchy to make decisions that overstep the limit of their knowledge, or take up a leadership position without consulting the other group members. In such situations, the team will begin to lose cohesion and stakeholders may fall back into their disciplinary sub-groups. In successful collaborative groups, while *a priori* roles play a role, they are also constantly negotiated during the development process with team organisation centred on stakeholders' capabilities and with different members taking up leadership roles at different times.

3.5 Maintaining group cohesion

Interdisciplinary collaboration requires more than a purely technical solution. Stakeholders also need to understand and believe in their contribution to a common goal. In this sense collaboration is more than just supplying goods or services, or working out who does what when and then delivering your responsibility. Collaboration understands that doing the work together produces a better outcome. When stakeholders share a high degree of trust within the team it supports high group cohesion and, in turn, a high degree of sharedness of a common goal. As Anthony, an industrial designer in a large consumer electronic company relates:

> Usually when one set of people in the team don't have respect for what the other people are doing, they get dismissive of the other person's role, which builds bad blood. I need to have respect for what the other person is doing otherwise they aren't going to respect me and we aren't going to get along, we aren't going to talk enough. (Anthony, Case 4: Pilot Study, Code 1.5)

Institutional settings and norms affect collaboration and point to the significance of social aspects of design activity. For example, organisational roles may impact upon the topics and sequence of a conversation, or a stakeholder may moderate their commitment to an idea to avoid personalising a discussion. Attending to social aspects of collaboration is essential for supporting group cohesion. Learning about other stakeholders' language and interaction style helps to deal with disagreements or conflicts when they arise.

Team size, team tenure, and form of communication have an effect on group cohesion. Moreover, group cohesion, the interrelatedness of stakeholders' ideas can be both a benefit and a constraint. High group cohesion may be constructive, but it can also lead to group think symptoms. While low group cohesion can cause the collaboration to lose a common purpose, which undermines productivity and causes delays. Group cohesion progresses through stages of divergence and convergence during a project, and the flow of group work and social interactions among stakeholders leads to cohesion and ability to achieve common goals. However, having too many goals, or when one stakeholder has a different goal from the other stakeholders, can result in a loss of integration and a disjointed development process that undermines investigating any single aspect sufficiently.

3.6 Managing knowledge and learning

Effective communication of project management activities and synchronisation of knowledge supports learning within the design team. However, as the following extracts show, learning cannot be reduced to effective communication. Rather, when communication goes beyond simply efficient dissemination of information between stakeholders, and towards the interactive construction of ideas through reciprocal processes of teaching and learning, the group can reach the innovation characteristic of interdisciplinary design work.

> [Most] clients come to us not just for the specific problem but also to learn how to be more innovative, and that means that they want to be involved… when we are teaching people how to be innovative, we talk a lot about a culture of innovation rather than an innovation process or an innovation, there are skills that make up that, there are tools and there are processes that you can hang things on, but in reality the way in which you succeed in being innovative is around the culture. (Mark, Case 4: Pilot Study, Code 2.4)

> [The] best way is to go and do a real job, but in that period we'll talk and discuss a range of things we are working on as well as future stuff, we work better in the field discussion-wise than formal meetings, we do the formal stuff when the guys deliver milestones, they'll come down to the department, they'll play our

> game, they'll come down to the department they sit in a meeting room and give a presentation. But the learning stuff goes on in the field. (Dave, Case 1: Industrial Design, Code 2.4)

High quality communication is a critical factor within collaborative design activity. The majority of the respondents described successful collaboration as efficient communication underpinning effective project management. The design process is more productive and completed quickly when communication of project management activities works well. The key process here is that high quality communication requires a high level of conversion of implicit knowledge in explicit knowledge. Moreover, clearly communicating explicit knowledge allows the team members to develop a common understanding of the project requirements and synchronise their mental models of the problem-situation.

Externalisation of knowledge is critical in collaborative design because there is no "place" where all team members store knowledge implicitly. Stories, or collections of images and prototypes transfers knowledge. Issues of time, confidentiality, and employee turnover affect the success of formal knowledge management systems. Moreover, there is also a process of knowledge transformation within the flow of design activity, and in circumstances where communication goes beyond information distribution and towards understanding there is knowledge synchronisation. In this sense, two-sided learning supports understanding where stakeholders explicate the part of their tacit understanding that the other stakeholder needs for further understanding of the problem or solution and vice versa. This implies that stakeholders are mutually responsible for each other's learning.

There are two forms of learning within collaboration, first, the formal training characteristic of describing a technique or method, and second, the informal sociocultural learning process that occurs during shared practice. In the first sense learning is an explicit task, while in the second sense learning is a more reciprocal process that can occur, for example, when stakeholders spend time immersed within the problem context and develop shared understanding of the issues. From the second perspective, learning does not only take place inside individuals heads, rather what individuals learn reflects the social context. The team's capacity to learn determines the level of innovation it achieves.

3.7 Contributing to culture

> Well there would be no benefit if I knew everything already. But I don't… it's an interesting question, what are the benefits of any conversation?… partly it's fun, partly you learn some stuff, it's life isn't it? Having a yarn, and if you think about the opposite, about what the cost would be of extreme isolation, of incarceration, disciplinary incarceration, that would be what you would do to someone who had been misbehaving. We are free to talk so we will. (Peter, Case 2: Architecture, Code 1.3)

Collaborative design is most successful when the passion for creating design work goes beyond producing just another product or commercial. Feeling that the work makes a contribution to the design discipline, rather than focussing on how much time it takes or the method used to create the outcome, ultimately makes for a more satisfying result. Collaboration is a process that involves looking outward beyond the immediate tasks of the project towards making higher-level contributions to the discipline of design and to encourage dialogue with the community.

4. The significance of informal Interactions within interdisciplinary collaborative design activity

According to Horst Rittel [32], only well defined problems are applicable to formal linear problem solving approaches. Rittel argues that complex problems are wicked problems, that is, indeterminate networks of issues with pros and cons to be approached through an evolutionary process of debate that systematically challenges statements by exposing them to different view points [33]. Since Rittel maintains that the design process required to address wicked problems is necessarily collaborative and political rather than merely technical, then informal interactions are significant because they support the social nature of collaboration. It follows that the design process should maximise participation to activate as much knowledge as possible. Therefore, integrating different viewpoints requires informal interactions to enable non-experts to express non-technical knowledge and participate.

Informal interactions influence the development of shared understanding in several different ways. First, analogical reasoning is not a formal logic for solving well defined problems; rather it operates through tentatively introducing knowledge to start a conversation to lead on to something else. Informal interactions support the tentative introduction of interdisciplinary knowledge that allows formal evaluation processes to take place. Second, as we have seen, immersion gives stakeholders direct experience of the issues and contexts of the problem-situation to understand what people do, what they value, and how they understand things. Immersing stakeholders and designers in the problem-context provides more opportunities to share conversations and to understand each other's worldview. It is not possible to develop the level of innovation characteristic of interdisciplinary collaboration by simply treating the user as a customer and asking them to describe their needs. Rather it is informal interactions that support users and stakeholders to express their implicit knowledge to designers. Third, informal interactions support integration of knowledge because they enable stakeholders to appreciate everyday practice, which gives context to knowledge-in-action, and consequently breaks down barriers between experts and non-experts. Furthermore, sharing simple sketches and basic artefacts during informal interactions supports the translation of knowledge from one disciplinary language to another more effectively than technical visualisations or models. Fourth, excessive use of jargon and formal language can create misunderstanding and conflict. Conflict often occurs when communication breaks down during high pressure situations. Sharing informal interactions allows stakeholders to gain insight into discipline specific language, which supports communication. Fifth, informal interactions support shared understanding because the process of working together to build shared understanding may be as valuable as having understanding. Furthermore, informal interactions support the interpretive approach to constructing shared understanding through team members' conversations and relationships.

Informal interactions support the cycle of iteration and prototype testing by because greater degree of trust encourages stakeholders to test their ideas as early as possible. Stakeholders test more ideas when they have the confidence to criticise their ideas. Moreover, ideas may not arrive on cue during specified formal meeting times, rather ideas may develop unexpectedly through on going conversation and talk. Informal interactions support innovation since they provide additional opportunities for interdisciplinary idea generation in-between specific formal tasks.

I showed that designers should take care to maintain the continuity of the design work because high uncertainty can cause breakdowns in the flow of activity. The design team can keep the development of ideas progressing by taking the time to manage the influence of hierarchical control of decision making, and by allowing opportunities for reflection. Informal interactions support the design team to maintain the flow of activity by supporting on-going conversation, consequently exchanges between stakeholders become more meaningful due to the greater number of opportunities for interactive reflection. Moreover, negotiating leadership roles as stakeholders explore issues reduces the impact of hierarchy. Thus maintaining the flow of design activity through allowing both ambiguity and control, and for the unplanned and unexpected to arise.

Meeting informally to get feedback and buy-in supports group cohesion since the new design ideas are not unexpectedly introduced during the pressure of a formal meeting. Further more, informal interactions support group cohesion because teams with a short history demonstrate greater external communication while teams with longer tenures favour internal communication [34]. According to Brown and Eisenhardt [34] frequent internal communication is essential to effective group work because it breaks down barriers and cuts misunderstandings, which then increases the amount of information conveyed and improves speed and productivity.

The respondents reported that collaboration requires more than a purely technical solution; stakeholders also need to feel they are contributing to a mutually beneficial common goal. Testing whether there are aspects of the client's brief that overlap with the interests of the designers requires informal interactions during the early stages of the design process.

Informal interactions support communication by encouraging dialogue rather than pure information distribution. Moreover, stories, images or models transfer knowledge informally rather than through formal codification. Furthermore, informal interactions support learning to happen in the field not only the boardroom. Here, informal interactions support the capacity of knowledge to spread by shared practice, rather than relying on the self-sufficiency of information or its capacity for replication.

Finally, respondents reported that collaboration is more successful when the stakeholders share passion for design practice. Feeling that their work made a contribution to the design discipline makes for a more satisfying result than focusing on time or process. Making a contribution to culture is a goal that goes beyond the formal specification of the project deliverables.

5. Concluding remarks

This paper presents results from an empirical study of interdisciplinary collaborative design in industry. The study found that informal interactions underpin the various design activities that are crucial for generating the innovative power characteristic of interdisciplinary design. The results imply that socio-cultural theories that take account of design activity in practice can complement prevailing cognitive models of designers' reasoning processes.

Support developed for design activity may be better tailored to practice by taking the influence of informal interactions into account. Consequently, the impact of theory on practice may be improved. Furthermore, organisations should structure their business models to support immersion of stakeholders together to take advantage of the innovative power of interdisciplinary teams to solve complex problems. New forms of enterprise social networking technology could potentially support informal interactions.

The realist position that this study maintains implies that the model of interdisciplinary collaborative design presented here could well be objectively wrong: the model may fail to capture the phenomena's real history and internal dynamics. However, because realists admit that their theories are fallible it implies that their theories are open to adjustment and growth. Consequently, I intend to undertake further research to validate the model and theory. This would involve formulation of hypotheses and testing by experiment. Ultimately, accurate prediction and explanatory power would be convincing evidence in favour of the model.

6. Acknowledgements

The author would like to gratefully acknowledge the interview respondents and case study members for generously giving their time to participate in this study. This study has been supported by Swinburne University of Technology.

7. References

1. Catledge, L.D. and C. Potts, *Collaboration during conceptual design*. Proceedings of the Second International Conference on Requirements Engineering1996: IEEE Comput. Soc. Press. 182-189.
2. Arias, E., et al., *Transcending the individual human mind - creating shared understanding through collaborative design.* ACM Transactions on Computer-Human Interaction (TOCHI), 2000. **7**(1).
3. Vande Moere, A., A. Dong, and J. Clayden, *Visualising the social dynamics of team collaboration.* CoDesign, 2008. **4**(3): p. 151-171.
4. Geisler, C. and E.H. Rogers, *Technological mediation for design collaboration.* ACM Special Interest Group for Design of Communication, 2000: p. 395.
5. Olson, G.M., et al., *Small group design meetings: an analysis of collaboration.* Human-Computer Interaction, 1992. **7**(4): p. 27-27.
6. Adams, R., et al., *Exploring the boundaries: language, roles and structures in cross-disciplinary design teams*, in *About designing: analysing design meetings*, J.T. McDonnell and P. Lloyd, Editors. 2009, CRC Press/Balkema: Leiden. p. 339-358.
7. Lewis, B.N. *Communication in problem-solving groups*. in *Conference on design methods*. 1964. New York: Macmillan.
8. Peng, C., *Exploring communication in collaborative design: co-operative architectural modelling.* Design Studies, 1994. **15**(1): p. 19-44.
9. Smulders, F., L. Lousberg, and K. Dorst, *Towards different communication in collaborative design.* International Journal of Managing Projects in Business, 2008. **1**(3): p. 352-367.
10. Sonnenwald, D.H., *Communication roles that support collaboration during the design process.* Design Studies, 1996. **17**(3): p. 277-301.
11. Lave, J. and E. Wenger, *Situated learning: legitimate peripheral participation*. Learning in doing1991, Cambridge: Cambridge University Press. 138 p.
12. Wenger, E., *Communities of practice: learning, meaning, and identity*1999, Cambridge: Cambridge University Press. xv, 318 p.
13. Castellan, N.J., ed. *Individual and group decision making : current issues*. 1993, Hillsdale, N.J : L. Erlbaum: Hillsdale, N.J.
14. Gernsbacher, M.A., S.J. Derry, and C.D. Schunn, eds. *Interdisciplinary collaboration*. 2005, Lawrence Erlbaum: Mahwah, N.J.
15. Cross, N., *Developments in design methodology*1984, Chichester: Wiley. 357 p.
16. Dorst, K., *Design research: a revolution-waiting-to-happen.* Design Studies, 2008. **29**(1): p. 4-11.
17. Durbin, P.T., *Philosophy of technology: practical, historical, and other dimensions*1989: Kluwer Academic Publishers.
18. Grant, D.P., N. Cross, and M.d. Vries, *Design methodology and relationships with science*, ed. D. North Atlantic Treaty Organization. Scientific Affairs1993, Dordrecht ; Boston: Kluwer Academic.
19. Blessing, L.T.M. and A. Chakrabarti, *DRM, a design research methodology*2009, Dordrecht ; London: Springer.
20. Cross, N., K. Dorst, and H. Christiaans, eds. *Analysing design activity*. 1996, Wiley: Chichester; New York. xi, 463 p.
21. Dwarakanath, S. and L. Blessing, *Ingredients of the design process: a comparison between group and individual work*, in *Analysing design activity*, K. Dorst, H. Christiaans, and N. Cross, Editors. 1996, Wiley & Son. p. 93-116.
22. Bucciarelli, L.L., *Designing engineers*1994, Cambridge, Mass.: MIT Press.
23. Feast, L., *Professional perspectives on collaborative design work.* CoDesign, 2012. **8**(4): p. 215-230.
24. Hughes, J.A., D. Randall, and D. Shapiro, *From ethnographic record to system design.* Computer Supported Cooperative Work, 1992. **1**: p. 123-141.
25. Vinck, D. and E. Blanco, *Everyday engineering : an ethnography of design and innovation*2003, Cambridge, Mass.: MIT Press.
26. Gaspar, P., *Explanation and Scientific Realism*, in *Explanation and its Limits*, D. Knowles, Editor 1990, Cambridge University Press: Cambridge. p. 285-295.
27. Mills, J., A. Bonner, and K. Francis, *Adopting a constructivist approach to grounded theory: implications for research design.* International Journal of Nursing Practice, 2006. **12**(1): p. 8-13.
28. Robson, C., *Real World Research: A Resource for Social Scientists and Practitioner-Researchers*1993, Oxford: Blackwell Publishers.
29. Hallberg, L.R.-M., *The 'core category' of grounded theory: Making constant comparisons.* International Journal of Qualitative Studies on Health and Well-being, 2006. **1**(3): p. 141-148.
30. Seale, C., *Quality in Qualitative Research.* Qualitative Inquiry, 1999. **5**(4): p. 465-478.
31. Friedman, K. *Theory Construction in Design Research. Criteria, Approaches, and Methods*. in *Common Ground, Design Research Society International Conference*. 2002. Brunel University, Stoke on Trent, UK: Staffordshire University Press.
32. Rittel, H. and M. Webber, *Dilemmas in a general theory of planning.* Policy sciences, 1973. **4**(2): p. 155-169.
33. Buchanan, R., *Wicked Problems in Design Thinking.* Design issues, 1992. **8**(2): p. 5-21.
34. Brown, S.L. and K.M. Eisenhardt, *Product development: past research, present findings, and future directions.* Academy of Management Review, 1995. **20**(2): p. 343-378.