Development of design collaboration skills

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This paper aims to advance our conceptual understanding of design collaboration, a domain-specific subset of collaboration skills that emphasises knowledge-sharing and knowledge-integration processes. This paper explores how design collaboration skills develop along with design expertise across three stages of experience. First-year bachelor students, master students, and design professionals took part in a design game to investigate their design collaboration skills. We assessed their design collaboration skills by analysing their sessions for the degree and quality of knowledge sharing and integration using a reflective practice analysis and an interpretative analysis of their conversation. It was found that the first-year bachelor students and the professionals outperformed the master students in terms of collaborative design performance. In finding this nonlinear relationship, we highlight the need to distinguish between design expertise and design collaboration skills and to treat them as independent concepts when assessing design team performance. Finally, through an interpretive analysis, we developed a typology of design collaboration approaches at the three stages of experience.

Keywords: design collaboration; design skills; co-operative learning; reflective practice; design understanding

1. Introduction

Collaborative design requires individual design expertise as well as collaboration skills. Research on design expertise has primarily focused on design skill development and the apparent differences between the design skills of experts and of novices (Zeitz 1997, Sonnentag 2000, Ahmed et al. 2003, Cross 2003, Kan et al. 2007). These design skills include cognitive skills such as analogical reasoning (Ball et al. 2004), handling multiple levels of abstraction simultaneously, and framing/reframing as well as practice-based skills such as visualisation (Sonnentag 1998) and information handling (Ahmed et al. 2003, Lawson 2004). Based on Dreyfus and Dreyfus’ (2005) model on the development of expertise, Lawson and Dorst (2009) distinguished six different stages of design expertise, novice, advanced beginner, competent, expert, master, and visionary, which provide a scale for the degree of design skill development.

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At the same time, the complexity of many of today’s design problems implies that no single actor has all the knowledge needed to realise a design task. Hence, collaboration has become an essential aspect of designers’ daily work (Badke-Schaub and Frankenberger 1999, Ostergaard and Summers 2009). This means that each participant holds only part of the required knowledge (Bucciarelli 2003), which makes collaborative design more complex than ‘individual’ design. The object of design is constructed as designers contribute their individual knowledge. Such knowledge includes process knowledge (e.g. how new products are to be introduced in the relevant industry, a company’s specific process for new product development, and beliefs about the ‘correct’ approach to design) and domain knowledge, such as manufacturing, cost estimation, and user interface design. The team members have to ensure that the relevant knowledge is shared and integrated effectively (Dougherty and Takacs 2004). To achieve this outcome, team members need to have skills for facilitating the integration of specialised knowledge across boundaries (Patnayakuni et al. 2007).

Following recent perspectives on social interaction processes in design (Medway 1996, Dong 2007, Luck 2009, McDonnell 2009), we view collaborative design as a discursive process (Luck 2010) in which a design concept is produced by talk-in-interaction. Bucciarelli (1994) characterised collaborative design by processes of negotiation and seeking trade-offs between alternative perspectives. These are aimed at developing a shared perspective in the team (McDonnell 2009). More specifically, Kleinsmann and Valkenburg (2008, pp. 370–371) defined collaborative design as,

the process in which actors from different disciplines share their knowledge about both the design process and the design content. They do that to be able to integrate and explore their knowledge in order to achieve the larger common objective: the new product to be designed.

Therefore, we view collaborative design as knowledge-sharing and knowledge-integration processes, both of which are of critical importance to the success of a collaborative design process (Kleinsmann et al. 2010).

To support the analysis of knowledge sharing and integration in the conversational setting of the design task studied in this paper, we adopt McDonnell’s (2009) view that knowledge sharing occurs in conversational turns in which each person contributes from his/her own area of expertise. Others respond to these conversational invitations and supply information. Knowledge integration refers to the collaborative negotiation process of aligning the individual knowledge bases in establishing a shared orientation within the team. This process occurs through tentative excursions where one person invokes the position or knowledge of the other person to propose or justify a design decision, provoking an expert response in turn (McDonnell 2009). McDonnell argued that focusing on conversational turns provides a method to study how design progression is collaboratively negotiated. This definition of knowledge sharing and integration is applied towards the assessment of their collaborative design performance.

In this paper, we view design collaboration skills as a specific subset of collaboration skills. While some of the previous work on design collaboration has addressed social skills such as conflict resolution, negotiating roles and responsibilities, and managing client relations (Lauche 2007), the emphasis here is on knowledge sharing and integration in the context of cross-functional teamwork in design (Edmondson and Nemhbad 2009). Compared with the study of design expertise, design collaboration skills have received less attention and little is known as to how they develop in relation to domain expertise. Therefore, the present study addresses this gap and focuses on the relationship between the development of design expertise and design collaboration skills. It investigates how designers with different levels of design expertise develop collaborative design skills in terms of knowledge-sharing and knowledge-integration practices of both task-related knowledge and process-related knowledge needed to execute a design project collaboratively by asking ‘How do design collaboration skills develop in relation to design expertise?’
The paper is structured as follows: first, we elaborate on the concept of design collaboration skills. Then, we report on an empirical study in which we compared collaborative design skills of designers across three different stages of design experience. We found a nonlinear relationship between the development of design expertise and design collaboration skills. In the discussion, we elaborate on the different knowledge-sharing and knowledge-integration strategies adopted by the designers of the different stages of design experience and substantiate conclusions in terms of the nature of design collaboration skills. Based upon these conclusions, we propose a typology of design collaboration skills and discuss implications for design education and future research.

2. Indicators for design collaboration skills

To assess design collaboration skills in situ during team conversations, we draw on the work of Schön (1984), who understood design as socially constructed. His concepts of knowing-in-action and reflection-in-action have been applied in design research (Lloyd and Busby 2001, Luck 2007) and used as a basis for the reflective practice-coding scheme developed by Valkenburg and Dorst (1998). According to Schön (1987), professionals behave as ‘reflective practitioners’ to shape their design activities in response to situational characteristics, by creating the so-called frames. A frame is a co-ordinating cognitive activity that is created through three alternating activities: naming, moving, and reflecting. Frames enclose both the problem and solution space and direct the team’s design activities. Designers use frames as ‘structures of belief, perception and appreciation’ (Schön 1987, Stumpf and McDonnell 2002). Therefore, frames are considered as sensemaking devices that establish the parameters of the design problem, its solution, or both (Gray 1996). Frames are discursively constructed during collaborative negotiation processes and include input of all team members and thus encapsulate the knowledge shared by the team. Teams have a clear focus as they frame (a part of) the problem and solution space together – they have a ‘shared way of seeing’. Framing as a team process, thus, results in effective knowledge integration, leading to intelligent decisions about the actions taken during that process (Schön 1987).

The other activities, naming, moving, and reflecting, can occur either inside or outside a frame. During naming, team members identify important elements that need the team’s explicit attention. Team members are moving when they are developing the design concept, for example, when they are generating ideas, exploring problems, or investigating the consequences of design decisions. Moves often contribute to the development of new frames or to changes in a frame. Moves help designers to redefine the design problem at hand. There are two types of moves: moves inside the frames are guided towards a (sub)goal, whereas moves outside the frames are unguided actions. The third activity is reflecting, in which team members turn their thoughts towards their current actions or what has been done so far. When reflecting, designers question the direction of their actions. Reflecting provides insight into the team’s progress and the quality of concepts developed. It can lead to re-framing of the design problem or new moves.

Naming, moving, and reflecting that occur within a frame are activities performed while having a shared way of seeing. Therefore, whether naming, moving, and reflecting occur inside or outside a frame has a direct consequence on the degree of goal-directed behaviour and shared rationality (Valkenburg and Dorst 1998). Design teams operating most of their time within a frame show a high level of goal orientation, since this type of communication results in determining what issues are to be taken into account and how to deal with these issues in order to complete (a particular part of) the design task at hand. Frames, therefore, provide the team with guidance towards further activities. The inability of design teams to construct frames implies that their actions are undirected. The reflective practice approach, therefore, enables us as researchers to observe the goal-directed behaviour and shared rationality of a design team. In turn, the level of
shared rationality and the goal directedness of a design team are treated as indications for the level of knowledge integration within the design team. In Section 3, we will explain how we operationalised these two indicators, goal directedness and shared rationality.

3. Research method

To investigate design collaboration skills across different levels of design expertise, we used a laboratory setting to simulate the design process using a design game as a standard task across all groups.

3.1. Simulating collaborative design with the Kantjil Design game

Since we are researching design collaboration skills, we had to ensure that domain knowledge would not influence the performance in this study. We needed a complex design task that was unfamiliar to all participants. Additionally, a setting was required in which participants with different knowledge and different means for representing the design had to perform knowledge sharing and integration. To meet these criteria, we used a design game based upon Bucciarelli’s (1999) Delta Design game as the setting for this study (for a detailed description of the Delta Design game, see Box 1).

Bucciarelli’s (1999) aim was to let design engineering students experience the social process of design by playing the Delta Design game. According to Bucciarelli (1999, p. 3),

> the Delta Design game is meant as an abstraction of the engineering design process which brings explicitly to the fore this vision of designing as social process of negotiation amongst participants who see, represent, analyse, and talk about the object, or subject, of design differently.

He wanted students to learn not only ‘to see’ what the other participants are doing, but also to experience ‘seeing as’ the other participants. As Bucciarelli phrased it,

> There are times during the Delta Design exercise when an outside observer will see all four participants pointing at the cluster [the pieces on the play board], motioning as if they were counting. What one doesn’t see is that they are all counting and figuring something different. (1999, p. 7)

In Box 1, we elaborate briefly on the characteristics of the Delta Design game.

Box 1. Delta Design game description.

The Delta Design game is played by a team of four participants who work on a design engineering task that requires collective efforts of each participant. They interact on a board (Figure 1) to design a building for ‘the Deltans’ – inhabitants of a planet called ‘Delta P’. Each participant has a different role. The Architect has to design a building that is pleasant to live in for the inhabitants of Delta P. The Structural Engineer is responsible for the construction of the building. The Thermal Engineer is responsible for the climate in the building. The Project Leader has to plan and monitor the design process and calculate the costs. For tackling this complex design task, the knowledge of all participants is needed; therefore, the four participants have to collaborate. The game explicitly simulates negotiation processes because the criteria of the four roles are contradictory on some aspects.

Kleinsmann and Van Der Lugt (2007) studied teams who played the Delta Design game. They confirmed that this game is well equipped to simulate a collaborative design process characterised by collaborative negotiation processes. However, they also identified two limitations. First, they found that the teams’ design collaboration process resembled mathematical problem solving rather
than designing, as the teams primarily tried to find a numerical balance between the different disciplinary requirements. They suggested that this was caused by the quantitative and explicit nature of the building requirements. In the Delta Design game, even ambiguous and intangible qualities such as the aesthetics, atmosphere, and meaning of the building could be translated into numerical values related to functional and perceptual characteristics. As such, the Delta Design game seemingly only incorporates the functional and perceptual aspects of design. This means it covers only two out of the four design elements that Medway (1996) identified by analysing which aspects can be discursively developed in design communication. The other two aspects, namely phenomenological and symbolic aspects, are not incorporated in the Delta game. As a result, the Delta Design game leaves little space for the more qualitative, interpretive aspects of a design.

Also Kleinsmann and Van Der Lugt (2007) argued that ‘seeing as’ in design engineering is also characterised by the designers’ various ways of representing the design. The different knowledge bases of the roles in the Delta Design game were mainly represented by formulas, thereby not seizing the full potential of simulating different ways of representing the design.

Kleinsmann and Van Der Lugt (2007) developed an adjusted version of the Delta Design game – the Kantjil Design game – that preserves its strengths but also incorporates a plurality of

<table>
<thead>
<tr>
<th>Features of the design game aimed at:</th>
<th>Delta Design game</th>
<th>Kantjil Design game</th>
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<tbody>
<tr>
<td>Simulating collaboration: Four team roles with different knowledge bases that are all needed to work on the design task</td>
<td>Present</td>
<td>Present</td>
</tr>
<tr>
<td>Simulating an unfamiliar design task: The design problem is aimed at a different planet on which different rules apply; therefore, people cannot use their domain knowledge</td>
<td>Present</td>
<td>Present</td>
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<tr>
<td>Simulating a complex design task: Different roles have different, partly conflicting requirements</td>
<td>Present</td>
<td>Present</td>
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<tr>
<td>Simulating ‘seeing’ the design differently: Different roles have incompatible knowledge, that is, give different meanings and use different concepts and jargon</td>
<td>Present</td>
<td>Present</td>
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<tr>
<td>Simulating negotiation: Team roles have conflicting requirements and goals, thereby simulating negotiation processes</td>
<td>Present</td>
<td>Present</td>
</tr>
<tr>
<td>Simulating all elements of the design: Different roles have qualitatively different conceptions of phenomenological and symbolic meanings of the design that are incommensurate</td>
<td>Not present</td>
<td>Present</td>
</tr>
<tr>
<td>Simulating different representations: Roles use different types of representations for their knowledge and the design</td>
<td>Not present</td>
<td>Present</td>
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</table>
phenomenological and symbolic meanings. The Kantjil Design game thus addresses qualitatively different ways of ‘seeing as’ that are incommensurate and multiple ways of representing the design.

In Table 1, we list the features of the two design games and show how these contribute to simulating collaborative design.

In Box 2, we briefly summarise the assignment of the Kantjil Design game.

Box 2. Kantjil Design game description.

The assignment of Kantjil is to build an ideal society on an island on a planet called Sutan. The design is built with Tangram pieces in different colours, each representing a different material. Yellow represents stone and is intended for buildings and houses; blue represents water; and green represents nature or agriculture. Each participant plays one of four different expert roles and is provided with task-relevant knowledge to build the island. The four roles are (1) the **Energy Expert**, who should ensure that the inhabitants have sufficient energy supplies; (2) the **Culture Expert**, who should guarantee that the inhabitants of the island feel comfortable and happy on an island with as many inhabitants as possible; (3) the **Health Expert**, who should pay attention to the health and well-being of the inhabitants; and (4) the **Landscape Architect**, who should create a good atmosphere and design the layout and configuration of the physical sites on the island. Before the game starts, the Landscape Architect prepares a layout that is based on mood boards provided in the role description. The criteria for each role are deliberately conflicting and, therefore, require negotiation and trade-off decisions. For instance, the role of the Culture Expert gives preference to building large metropolises to provide entertainment, whereas the role of the Landscape Architect is to create scattered villages with nature and recreational areas in between. This role is provided with mood boards to visualise the desired ambiance on the island. The Culture Expert strives to make the inhabitants happy, for which a number of qualitative requirements are introduced. In addition, the knowledge creation approach and means for representing the design differ between the roles. For example, the Landscape Architect is instructed to make drawings of concepts of islands, while the Energy Expert uses mathematical formulas to determine the total energy yield of his plants (see Table 2 for more examples). Figure 2 shows the Kantjil Design game board with an example solution; Table 2 illustrates an example as to how the meanings of the building blocks differ per role.

Table 2 shows how we operationalised the two aspects that differ from Delta Design. While the team members share the game pieces as a common, external representation, each role has its own

<table>
<thead>
<tr>
<th>Simulating different representations</th>
<th>Energy Expert</th>
<th>Culture Expert</th>
<th>Health Expert</th>
<th>Landscape Architect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formulas</td>
<td>Tables</td>
<td>Rules</td>
<td>Mood boards</td>
<td></td>
</tr>
<tr>
<td>Tangram pieces are referred to as ’units’ that have a certain density. These units determine the energy yield and demand.</td>
<td>Tangram pieces represent the amount of inhabitants. Piece size relates to the atmosphere (joy, despair) on the island.</td>
<td>Tangram bits are referred to as ’pieces’, which have a certain density. Pieces have implications for the flow of fresh water on the island.</td>
<td>Pieces are expressed in their absolute quantity – size does not matter. The patterns and shapes are related to the meaning that the buildings have for the inhabitants.</td>
<td></td>
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</table>
representation for the knowledge underlying the common representation. In addition, the game pieces are not automatically a shared representation, since each role has its own representation of what the pieces mean. The teams must share and integrate their knowledge in order for them to develop a shared representation about the game pieces.

3.1.1. Sample and data collection

To compose teams with different levels of design expertise, we recruited nine teams of designers from three levels of experience: (1) first-year bachelor students with half a year of design experience as part of their education (teams B1, B2, and B3); (2) master students with about 5 years of design experience as part of their education (teams M1, M2, and M3); and (3) professionals with about 7–10 years of design experience, of which 2–5 years were in industry (teams P1, P2, and P3). The first-year bachelor teams and two of the master teams participated in this study as part of a course. The assignment was used as a prompt for reflection upon their teamwork, but it did not constitute part of their marked performance. All first-year bachelor team members had recently graduated from high school, with age ranging from 18 to 20, average 18.3 years (SD = 0.65). In order to complete our sample, we recruited a third master team, and each of these team members was paid an honorarium of 25 euros for participating. Three of the four people of this team had previously worked together. The age range of the master teams was between 23 and 27 years, with an average of 24.0 years (SD = 1.38). The professional teams were recruited through personal contacts and they agreed to participate in order to reflect on their teamwork. The average age was 31.7, ranging from 24 to 40 (SD = 5.0). All members of the three teams had previous experience working together as a group.

The participants were given 30 min to read the general instruction, which explained how to play the game and gave role-specific information for each player. The participants could ask the researcher present during the simulation for assistance when the instructions were unclear to them. The team members were instructed not to let other team members read their role descriptions. After reading the role instruction, the Landscape Architect would start by making a concept sketch of the island, which formed the starting point for the simulation. All team members were present in the laboratory for the simulation part, which took about 75 min. The simulations were videotaped. After the game, the researcher facilitated a discussion between the team members to reflect upon their collaborative design approach, their design approach, and the issues they encountered. The researcher was trained as a design coach and drew on this experience. In addition, the team members filled in a survey that consisted of general questions on teamwork, such as the level of
conflict, the team’s productivity, the level of shared agreement on the Kantjil settlement designed at the end of the game, and the sense of teamwork. Both the post-simulation discussion and the survey were used to gauge how participants perceived the Kantjil Design game and their collaborative design behaviour during the game.

3.1.2. Data analysis

The data analysis consisted of three steps based on a verbatim transcript of the explicit team communication during the simulation (Table 3). First, we checked if the teams actually varied in their design expertise in terms of Lawson and Dorst’s (2009) version of Dreyfus and Dreyfus’ (2005) model. Second, we conducted an in-depth qualitative analysis for periods of knowledge sharing and integration. Finally, we assessed each team’s design collaboration skills in terms of the reflective practice coding introduced by Valkenburg and Dorst (1998). For our analysis, we relied on the transcripts of the team communication as well as on the post-simulation discussion with the team members.

For the first step, the first author carefully read the transcripts and identified process-directed activities: those parts of design conversation in which participants comment on the design process (rather than on the design itself, which would constitute design content). In addition, segments in which the team formulated the design problem, generated solutions, or evaluated proposed solutions were identified. These sections revealed how the teams approached the design task. We checked if the participants recognised the complexity of the design problem and whether they were able to create a solution that balanced all requirements. Then, we categorised their behaviour in terms of the design expertise model of Lawson and Dorst (2009).

For the second step, we aimed to gain more insights into the design collaboration approach adopted by the teams by qualitatively analysing how the teams shared and integrated their knowledge bases. Based on McDonnell (2009), we identified periods of knowledge sharing through conversational turns in which each person contributes from his/her own area of expertise and others respond to the information supplied. Likewise, we identified periods of knowledge integration through conversational turns wherein participants invoked the position or knowledge of another participant to propose or justify a design solution or decision (McDonnell 2009).

For the third step, the quality of the design collaboration was assessed through a detailed coding process following the reflective practice method. First, the activity that a team discursively performed was identified based on the content of the team communication (e.g. Dorst and Dijkhuis 1995). The unit of analysis was episodes, which consists of a part of the transcript in which one activity is performed by the team. All episodes were described with a short title, such as ‘making an inventory’ or ‘combining ideas’, resulting in an outline of the flow of activities. The next step was to assign the three activities, naming, moving, and reflecting, to the episodes (e.g. ‘making an inventory’ and ‘combining ideas’ are moves because they are experimental actions). In the final step, we identified frame shifts in the team communication to study the process of negotiating frames among team members. Frames were detected through association and dissociation markers (Stumpf and McDonnell 2002). An association is a move in an argumentation scheme based on the team members’ knowledge structure when they have agreed what the facts of the situation are; in other words, the team members knew what each team member would accept as assumptions and as their knowledge structure at that moment. Strings of associations form a frame and these strings were coded accordingly. When participants introduced a dissociation that was followed by another string of associations, a new frame was constructed. A dissociation can be seen as a suggestion by a participant to adopt a different perspective or ‘seeing it differently’ (Stumpf and McDonnell 2002). Sequences of dissociations result in unfocused discussions and may eventually lead to team conflicts as no shared way of seeing is acknowledged.
Table 3. Methods for determining quality indicators for design collaboration skills.

<table>
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<tr>
<th>Analysis type</th>
<th>Analysis steps</th>
<th>Safeguards for reliability and validity</th>
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<tbody>
<tr>
<td>1. Screening the level of design expertise</td>
<td>Establishing whether teams showed the expected level of design expertise based on their learning stage by: 1. Identifying segments in the transcripts that concerned a discussion of the design process. 2. Identifying textual evidence of the design expertise levels (Dreyfus and Dreyfus 2005, Lawson and Dorst 2009) in these segments. 3. Checking the researchers’ interpretations against the teams’ own reflections from the post-simulation discussions</td>
<td>1. The first author collected textual evidence for the level of expertise; the second author checked the first author’s interpretations of the evidence to safeguard the reliability. 2. The findings were checked against the teams’ own interpretations to verify the consistency of the interpretations made</td>
</tr>
<tr>
<td>2. Characterising the design collaboration behaviour</td>
<td>Inductive analysis to advance the conceptual understanding of the development of design collaboration skills by means of 1. Searching for textual evidence of knowledge-sharing and knowledge-integration practices based upon the definitions of McDonnell (2009). 2. Developing descriptive categories to characterise the teams’ design collaboration behaviour</td>
<td>1. Constant comparison method (Corbin and Strauss 2008): assessing whether the descriptive categories concerning the knowledge-sharing and knowledge-integration practices were conceptually distinct, by asking questions such as the following: Are these instances different from the other instances? Categories were merged and integrated when appropriate. 2. Categories were developed by the first author and checked with the second author to safeguard consistency</td>
</tr>
<tr>
<td>3. Assessment of the teams’ design collaboration skill</td>
<td>Reflective practice coding of goal directedness and shared rationality by means of 1. Determining the beginning and the end of design activities. 2. Segmenting the transcripts into episodes of one design activity based upon Valkenburg (2000). 3. Labelling each episode in terms of its content. 4. Coding episodes as names, moves, or reflections, as proposed by Valkenburg and Dorst (1998). 5. Identifying associations and dissociations in the protocol for frame detection, as proposed by Stumpf and McDonnell (2002). 6. Labelling each frame in terms of content. 7. Calculating the total duration of frames as percentage of the entire meeting and the ratio of moves inside and outside the frames (based on a word count of the transcripts)</td>
<td>1. The first author was trained by Valkenburg to conduct the reflective practice coding and he trained the second author to do so. 2. The inter-coder reliability was calculated between the two coders with the use of Cohen’s kappa. A kappa value of 0.72 indicated an acceptable level of inter-rater reliability</td>
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</table>

The team’s goal directedness was operationalised as the percentage of moves inside versus outside a frame as shown in Figure 3. The amount of shared rationality was operationalised as the percentage of total communication that a team spent within a frame. Since the unit of analysis (‘episodes’) often differed considerably in length, we decided to determine the duration of the frames as a percentage of the total playing time as well as the ratio of guided to unguided moves based on a word count.

The transcripts of the first-year bachelor teams and the master teams were coded by either the first or the second author and checked by the other. The inter-rater reliability was calculated using a part of the transcript of a professional team that contained all four reflective practice activities
at least once. A Cohen’s kappa coefficient of 0.72 indicated that the two researchers established a reliable approach to coding the data.

4. Results

First, we report the screening of design expertise as exhibited by the teams to check whether their behaviour was in line with what could be expected in terms of their level of design experience. Second, we describe the interpretative analysis of the collaborative approaches that the teams adopted to share knowledge and achieve knowledge integration. Third, the results of the reflective practice analysis are reported in terms of a team’s level of shared rationality and goal-directed behaviour.

4.1. Screening of levels of design expertise

The analysis of the design approaches confirmed that the design expertise level was in line with what could be expected based on the level of formal training, which will be shown in the continuation of this section.

4.1.1. Design expertise of the bachelor teams

As expected, the first-year bachelor teams behaved like what Lawson and Dorst (2009) called naïve/novice designers, in that their design approach can be characterised by a series of trial-and-error steps. The following excerpts from each of the different bachelor teams are representative of a novice design approach:

*Team B1*: H1: I think we just need to draw something
*Team B2*: C: so let’s just try and move everything around
*Team B3*: C: Ok, we just lay down something, and then.
E: And then we discuss.

They tended to search for the easiest solutions and were unable to grasp the full complexity of the entire design problem (the game). They hinted at problems, but dealt with them element per element (e.g. a city) without considering the relationship of that element with others (e.g. the relationship between the structure of a city and the fields needed to feed its inhabitants). They also overlooked the complexities of each design problem; when such problems arose, they ignored them rather than deferring them or dealing with the complexity. At times, team members realised this, as is illustrated by the following excerpt from team B1:

C: I think we have more things we need to keep in mind but it’s too much
However, in the episode, this insight did not lead to anything and the team members continued their discussion.

4.1.2. **Design expertise of the master teams**

The behaviour of the master teams corresponded to what Lawson and Dorst (2009) called *advanced beginner* – designers who understand how to design and take situational factors into account. In our sample, the master teams all started with a detailed investigation of all requirements by sharing the information given in their respective briefs. This is shown in the following excerpt from the master team M3, with requirements shown in boldface:

> C: …I don’t know if your paper says anything about it but transportation is very hard on this island because it’s very rocky so then you have to climb over the rocks so the *transportations goes by rivers* so they can transport the food from the farm fields by the river to the cities.
> H: I have the exact opposite in my thing. *River needs to flow from fields to cities*, because when they pass a field that is four pieces or larger the water gets contaminated and [the Sutaners] will become ill if you let flow the river in reverse from the field to the city
> C: oh, I don’t care about the direction of the river, as long as there are rivers and boats can flow in it
> A: ok, but *rivers are going to be important*

Due to their detailed analysis of the requirements, the master teams recognised the complexity of the design problem, which is part of expert design behaviour. However, being able to see the connections between elements did not enable the master students to address them. They referred to small chunks of information and used concrete examples rather than collectively constructing an overall vision.

4.1.3. **Design expertise of the professional teams**

The professional teams behaved according to what Lawson and Dorst (2009) described as an *expert* – a problem solver who immediately recognises the most important issues, plans appropriately, and reasons what to do. Although the professional teams could not draw on their expert domain knowledge for playing the game, it seemed that because of their procedural knowledge concerning complex problem-solving and design processes, they immediately searched for interdependencies between requirements and elements and prioritised and planned accordingly. Therefore, it appears that because of their advanced procedural knowledge, the professionals were able to use the supplied new domain knowledge effectively. The professional teams seemed to follow a design approach without explicitly discussing it, which is not surprising given that they had worked together on a daily basis. Teams were more likely to start from an overall concept, as shown in boldface in the following excerpt from the professional team P1:

> A: I already tried to make some squares and stuff. Just fill it up, the entire board. **The general idea was to start with a river.**

As soon as the river was built, team P1 evaluated it (shown in boldface):

> A: We need a river and a number of small lakes. Well, that’s what I’m supposed to do I guess. So we need some small lakes. Well, what do you need for a lake?
> H: Well, more than three pieces because of the germs.
> C: For me **it’s good to have small lakes.**
> H: One or two pieces or do we need more?
> A: We’ll check those later.

This discussion illustrates that as soon as the professional teams got stuck in details, they explicitly decided to postpone judgement and continued working on the design problem. This is an example of expert design behaviour.
The members of team P3 also started from the Landscape Architect’s plan and improved it by creating ‘long cities’ to achieve the aim they set for themselves: ‘to make the biggest population on the island as possible’. They recognised that the restrictions for creating a large population were hidden in the detailed briefing provided for each role.

Team P2 developed a modularised design concept – ‘a module with good connections’ – and replicated the module several times on the game board. As is shown in the following quote of Team P2, the members kept referring to the ‘connection’ between the modules:

C: then more green is connected to the city, and less green and blue is connected to each other so that’s better for the cultural
A: ok
H: but it needs to be irrigated still
E: but if we move the river a little bit
C: yeah but then you have again the connection

In summary, the design teams showed variation in terms of their design expertise and the level of design expertise corresponded with the level of experience. Thus, they provided a suitable sample for the comparison of design collaboration skills across design skill stages.

4.2. Characteristics of design collaboration behaviour at different levels of design expertise

The second step in our analysis addressed how the teams shared and integrated their knowledge to characterise the design collaboration approach (see step 2 in Table 3). During the post-simulation discussion, we found no evidence of any problems in collaboration in terms of social interaction. This was also confirmed by the survey that all participants filled out immediately after playing the game.

4.2.1. Design collaboration behaviour of the bachelor teams

For the first-year bachelor teams, we found limited knowledge sharing. They only contributed their area of expertise to the team, but there was no response from the other team members. Instead, teams agreed on compromises without an in-depth discussion with an attitude of ‘you want this, you get it; and I still can get my idea on another part of the island’. This is illustrated by the following quote from team B3:

H: Everyone has their thing. If there is a problem just say it and we make an adaptation.

Since teams did not engage in negotiation, knowledge was only integrated on a shallow level (without even investigating contradictory meanings of concepts that were discussed), as the following example from team B2 shows. The Culture Expert suggests a solution based on making large cities, based on this actor’s knowledge that the city size is based on the surface area of the Tangram pieces.

C: So I think the best is to make two cities
E: I think…
A: Small cities
C: Big cities, as big as possible, not too big, but as big as possible
P: Maybe we can make a city with several surrounding villages
A: Yeah but also green and water
C: Yeah I think we can better make a few more cities than a lot of villages around

The example shows that team B2 made a number of fundamental decisions about the size and number of cities, but this led to compromises in terms of the aesthetic design of the atmosphere,
the domain of the Landscape Architect. They discussed neither the details nor the consequences of these compromises. If they would have discussed the difference between meanings of the discussed concepts, they would have identified potential optimal compromises. The example shows that a decision was made in only six conversational turns during which the team members shared several design solutions without justifying these in terms of the dimensions of the Kantjil game. They were, for instance, unconcerned by requirements and did not address why their solution ‘big cities’ was a viable option. The team members contributed new knowledge by making suggestions from their role perspective, such as changing the discussion topic to needing ‘green and water’, but they did not question each other. In these six conversational turns, the design solution changed radically. In making this shift, the team members did not invoke or provoke the other team members, and as a result, no knowledge was integrated. When they discovered the consequence of this decision later in the process, they optimised the solution – again on a shallow level and without investigating the different meanings of the concepts used.

4.2.2. Design collaboration behaviour of the master teams

The master students showed a different approach compared with the bachelor teams in that they spent a lot of time on knowledge sharing. Team members started by sharing details from their role instructions to explore the situation and they discussed the contradicting requirements. The following example from team M1 shows how the teams engaged in a level of detail that was more than needed and could potentially lead to cognitive overload. We typeset each new contribution of knowledge in boldface.

A: What’s the reason of having a maximum of four pieces connected?
H: Then fertilization is not necessary.
E: So we should try to have very small green parts.
C: Yes between two and four.
A: And your reason was?
C: To have farmland for fruits and vegetables and that sort of things
H: We could have bigger parts of green but then only four should be arable. If we have more pieces here, this is nature reserve. If cities are bigger than 500 000 people, then they need nature reserves...

The example shows that the Landscape Architect invoked the knowledge of the Health Expert and then the Energy Expert integrated the two visions, by proposing a design solution, which was agreed by the Culture Expert. Also, the Landscape Architect asked the Culture Expert for an opinion about the topic. Then, the Health Expert opened up the discussion again by adding more knowledge to the conversation. This was typical for the conversations of the master teams. After this kind of detailed negotiation regarding the interactions between the four main building blocks (a real attempt to integrate their different knowledge bases), all master teams got stuck. Their detailed breakdown of the objectives into constituent parts was not matched by an ability to put all the elements into a coherent whole, and this led to failed design concepts that could not meet the roles’ individual objectives. Due to time constraints, team members optimised parts of the design concept that they had created individually. This led to an unfocused discussion, which is illustrated by the following fragment from the transcript of team M2 that took place at the very end of the game.

H: I have more blocks. I’m putting some green over here: nature.
A: Now it fits
E: Yes.
C: I can’t do that.
E: Stay away from it.
C: Sorry.
H: This is nature.
A: And now we have a windmill park.
C: I still need a bit more city…

What hampered this team’s performance was its inability to reconcile the design approach with the collaborative design approach towards a common overall goal. In particular, the team members were unable to reconcile each other’s level of focus. As the Landscape Architect of team M1 concluded after playing the design game,

In the end I missed the higher end goal … I miss some requirements on the end goal, perhaps some more concrete ones … But on the other hand you should define your own end goals … maybe we could have done that better.

4.2.3. Design collaboration behaviour of the professional teams

For the professional teams, we found a more focused form of sharing: they only shared their priorities. The professionals started by explaining their roles almost immediately and relied on each other’s knowledge to solve the design task collaboratively. This can be illustrated by the role description that the Energy Expert of team P1 provided to the team:

G: I have to ensure that everybody has enough energy available. They supplied me with a couple of data, which allows me to calculate how much energy is produced on the island. And I already have a warning that it is going to be quite a considerable part of the surface that is needed for energy.

The Health Expert of team P3 gave a similar briefing and explicitly stated the importance of integrating and subsuming each other’s knowledge in the last sentence:

H: What I see here is that you’re the Landscape Architect, because you should have prepared some stuff already. The Cultural Expert, that’s you and you are the green-energy-man. Is that correct? I’m the Health Expert. We have to put these together and everyone knows what he wants for his specialty.

Furthermore, the collaboration approach of the professionals was accompanied by explicit debate and negotiation. In the excerpt given below from team P2, the professionals showed that they were able to integrate knowledge through negotiation:

E: That’s true but for the energy, to get energy from that it’s really
H: Not good
A: Maybe we can think, this is very structured: if we multiply this we have the right combination, the right balance
E: Not good because I have one big connected place
C: It’s better to have big blue and green
A: But maybe we need a smart connection then
E: That’s possible
H: You are looking for the optimum right?
A: Yeah
P: Something yes
E: Then you can
By reiterating the contradicting requirements (in boldface), the Culture Expert sharpened what should be restructured:

C You don’t like the cities to be big so we can’t build a really big city with a big for my point of view that would be best to have a big city, one big piece of water and one big piece of green for my opinion that would be the most perfect
A So we need to have a balance because
E For me the two of us it really because the energy usage of a metropolis is higher than a village and a village a square uses only a 1000 units and in a metropolises a square uses 2500
C Yeah but that’s because in a village you can have 4000 people living and in a metropolis 35000
E Ok well yeah
C So therefore
H Need more energy

Eventually, through this process of negotiation, the team created a more balanced, integrated solution by restructuring the unit and the ‘smart connection’:

A Can’t we make a smart connection and if we link this to this their linked so maybe it’s behaving like a metropolis if we multiply this but it’s still a very open and friendly living environment so we
H But can we do, you want to leave this one
A But for now, now we have the amount I think we need to restructure them
H But we need the structure, so if we need this big thing for the energy so maybe we can change this around a little bit

4.3. Reflective practice analysis of goal directedness and shared rationality

Table 4 provides an overview of the results of the reflective practice coding as described in detail in step 3 in Table 3 and shown in Figure 3. The first measurement was the ratio of moves within and outside a frame. If moves take place within a frame, these actions are seen as goal directed. Table 4 shows that the professionals displayed the highest level of goal-directed behaviour (between 95.7% and 76.5% of their moves occurred within the frames), followed by the first-year teams (between 83.3% and 73.9% of their moves occurred within the frames). The master teams acted in a less goal-directed manner – only between 37.9% and 50.0% of their moves occurred within the frames.

Team P2 was an exemplar team in terms of goal directedness. In this team’s case, naming led to goal-directed moves. Team members started naming the most important issues of their roles. Then, they started building a river, which formed the starting point of their concept and constructed a city later on. Based on the river and the city, they improved the initial concept with their main aim in mind: to ‘build an island that can be inhabited by as many happy Sutaners as possible’. Despite the fact that the members of team M3 created four different frames, they had many unguided moves in between, which was not an efficient, goal-directed approach.

Second, to determine the extent to which a team established a shared rationality, we calculated the percentage of time that a team operated within a frame. The first-year bachelor students communicated, on average, 78% of their time within a frame; the master students, on average, 39%;

<table>
<thead>
<tr>
<th></th>
<th>First-year bachelor students</th>
<th>Master students</th>
<th>Professionals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B1</td>
<td>B2</td>
<td>B3</td>
</tr>
<tr>
<td>Goal directedness: percentage of moves inside the frames versus moves outside the frames</td>
<td>76.5</td>
<td>83.3</td>
<td>73.9</td>
</tr>
<tr>
<td>Shared rationality: percentage of the meeting that a team was ‘in’ a frame</td>
<td>76.0</td>
<td>81.3</td>
<td>77.8</td>
</tr>
</tbody>
</table>
and the professionals, on average, 80%. This means that the first-year students and the professional teams were substantially better at establishing a shared rationality than the master teams.

The members of team P2 showed the highest level of shared rationality in our sample. They adopted the plan prepared by the Landscape Architect and started building immediately, which enabled a quick focus. Difficulties and contradicting requirements were resolved by developing a module that contained ‘good connections’. The members of team B2 also established a high level of shared rationality. They constructed frames quickly and remained focused during the entire simulation.

The three poorly performing teams were M1, M2, and M3: team M1 constructed a frame quickly but completely lost its initial focus shortly thereafter. Team M2 started by sharing the role descriptions extensively, which was time-consuming. Eventually, this team created only a short frame at the end of the game. Team M3 alternated between short periods within a frame and long periods in which the team acted outside a frame.

5. Discussion and conclusion

This paper investigated the development of design collaboration skills in relation to the accompanying stage of design expertise, which, in the population of design teams studied, corresponded to their level of experience. The results showed the following patterns in the three different groups: the first-year bachelor teams with their relatively unsophisticated design approaches managed to collaborate by sharing limited amount of information. They tried various design solutions based on knowledge held by individual team members. Since the contributed knowledge generally occurred within a frame, the teams appeared to be goal directed and have shared rationality. Thus, in terms of our measure of collaborative design performance, they appeared to behave competently, but did not address the complexity of the design task.

The master students were more aware of the complexity of the design problem, which is evidenced by their extensive information-sharing conversations, as if the teams were attempting to learn as much as possible before solving the design problem. Like the bachelor teams, they shared their knowledge by recapitulating descriptions from the game instructions. They were more aware of situational factors and the complexity of the task, but got lost in reiterating empirical details, such as the number of pieces instead of the overall plan. They were unable to condense the knowledge contributed by the team members into general principles to address the design problem, which hampered their ability to design collaboratively. They simply overwhelmed each other with unfiltered details about their roles, rather than discussing the overall design concept and priorities integrating the different knowledge bases. This led to their getting stuck in needless detail, leading to little shared rationality and poor goal directedness.

Only the professional teams showed both high-level skills in design and design collaboration: in terms of their design expertise, they behaved like expert designers. They saw the design problem in its complexity and, thus, rather than dwelling on its complexities attempted to derive a general principle to address the design problem. They succeeded in condensing their knowledge into conjectures for approximate solutions such as ‘connected’ cities. The transcripts of their conversations provide examples of team members summarising and interpreting the implications of each other’s knowledge bases from others’ perspectives including their own. These strategies for knowledge sharing and integration enabled them to focus their discussion on the level of goals rather than on that of details.

Based on the analysis of these findings, we conclude that the degree and quality of knowledge sharing and integration are important distinguishing characteristics between novice and expert teams. In the following sections, we will elaborate on these findings by providing theoretical
implications and implications for design education. In the last part of this section, we will discuss the limitations of our research and provide guidance for future research.

5.1. Implications for the concept of design collaboration skill

If we compare how the teams shared knowledge in terms of the distinctions introduced by Klimoski and Mohammed (1994) and Cannon-Bowers and Salas (2001), we can see that the teams shared knowledge in a different way. The first-year bachelor teams contributed overlapping knowledge. When they shared knowledge, it was generally by contributing specific details directly pertinent to the matter at hand. They tried to build common knowledge but only at a descriptive level without justifications and ‘tentative excursions’ (McDonnell 2009). The master students shared all the information provided in their role descriptions and tried to integrate these different perspectives to achieve common knowledge, but they were unable to progress towards a general principle or procedure based on their common knowledge. The professional teams adopted a goal-oriented approach by prioritising and sharing only the most important knowledge, which is knowledge that allows them to reduce the problem to its fundamentals. The professional teams, therefore, exhibited a distributed knowledge system; they relied on each person knowing their role properly and that not everyone needs to know everything in order to succeed in a design project. Such a distributed system resembles the concept of a transactive memory system as proposed by Wegner (1987), which is a set of individual memory systems, which combines the knowledge processed by particular team members with a shared awareness about who knows what. Austin (2003) found a positive relationship between team performance and a team’s transactive memory system development, which is in line with the smooth design processes of the professional teams. This study showed that the creation of a distributed knowledge system by means of sharing knowledge at the appropriate level of abstraction and detail appears to be a key design collaboration skill. It enables knowledge integration to create a design concept that contains knowledge from all team members. This may appear to be a fairly evident truism, but only the professional teams achieved this kind of design collaboration approach.

The concept of collective cognition as defined by Gibson (2001) allows us to understand what happened with the different teams on the three levels. Gibson defined collective cognition as ‘the group processes involved in the acquisition, storage, transmission, manipulation and the use of information’ (pp. 122–123). Collective cognition arises through group processes of accumulation, interaction, examination, and accommodation. Figure 4 shows these group processes and the accompanying sub-processes. Drawing on Gibson’s model helps to explain why the first-year bachelor teams and the master teams did not reach the stage of design collaboration skills of the professional teams.

For the first-year bachelor teams, their collaborative design approach of knowledge sharing as needed suited the trial-and-error design approach. Because they acquired the information provided on a shallow level, the other collaborative processes also took place on a shallow level resulting in a rather smooth collaborative design process, leading to a high level of shared rationality and goal directedness. The master teams, however, acquired the information provided on a deep level of detail. Given their limited experience and design expertise, this made them incapable of filtering and storing the correct information individually. Due to this, they got stuck while they were

![Figure 4. The phases and sub-phases that comprise collective cognition (based upon Gibson 2001).](image-url)
interacting, examining, and accommodating the team members. Therefore, for the master teams, their collaborative design approach of detailed knowledge sharing reinforced their inability to solve the design problem on an individual level, which was shown by the low amount of shared rationality and the lack of goal directedness.

This finding is in line with that reported by Boos (2007), who argued that a team must carefully weigh the benefits and costs of shared and unshared knowledge, which was something that the master students did not do optimally. The perceived complexity of the design task made it difficult for the master students to share their knowledge in a sensible manner.

Finally, we propose a preliminary typology of collaborative design skills similar to the model of design expertise proposed by Lawson and Dorst (2009). Such a typology will enable designers and design educators to discuss the teams’ progress in terms of their design collaboration skills. We distinguish the following three stages of development of collaborative design skills:

*The naïve integrator:* who does not fully understand the design information available and who, therefore, shares his/her design knowledge on a shallow level. Knowledge integration with team members takes place at this shallow level, resulting in a design concept that is based upon trial and error.

*The extensive sharer:* who drowns in the design information available and who, therefore, shares too much detailed knowledge by contributing a new topic without subsuming prior knowledge. This results in a chaotic design process and a design concept that is based upon chance.

*The expert integrator:* who understands the design information available and who is able to create a transactive memory system with team members. This makes the knowledge-integration process effective and efficient. This results in an integrated knowledge and a design concept that embodies the knowledge of the different team members.

5.2. Implications for design engineering education

Acquiring relevant information is an important task for design engineers (Marsh 1997, Ahmed and Wallace 2004, Badke-Schaub 2004, Restrepo 2004), since the quality of the design outcome is dependent on it (Badke-Schaub and Frankenberger 1999). Empirical studies reported that design engineers spent, on average, up to 80% of their workday searching for information (King et al. 1994) and that the majority of design engineers’ information searches occur via face-to-face interactions with other people (e.g. Court 1997, Badke-Schaub and Frankenberger 1999, Wallace and Ahmed 2003) – rather than searching for information in a documentary source. This emphasises the importance of learning how to collaborate with other people during design projects.

Since design engineers are educated as generalists, it is typically their role to build bridges between disciplines, which means that they need to have good design collaboration skills. Design engineering education is often studio based, and teamwork is recognised in practice. However, design collaboration skills are not necessarily taught explicitly and there are hardly any guidelines that specifically imply knowledge-sharing and knowledge-integration processes in the context of design collaboration. Design collaboration skills are apparently learned ‘on the job’, which is suggested by the professionals in our sample, who showed that they gained design collaboration skills. Yet, the process of learning collaborative design could be guided better in order to speed up this process or to raise the quality.

We propose two interventions that could improve collaborative design skills: first, we propose that design engineering students should be educated about the levels of design collaboration skills. It goes without saying that learning objectives should be based upon these levels in courses in which they work in teams. The developer of a design course should keep in mind the complexity of the design task and whether it is an individual or group task. When a tutor wants to improve the design
expertise of a student, he/she should increase the complexity of the design task compared with the previous one. However, the assignment provided should be an individual assignment. As soon as the student passes the assignment and actually improves design expertise, the student could work on a similar task in a team in order to learn design collaboration skills. Second, we recommend that students need to obtain insights into their current collaborative design skill level. A way to do this is through experiential learning with directed reflections. Lloyd et al. (1995) showed that students could learn to reflect upon their design skills by recounting their design process as a story: students videotaped their design process and, in editing the video, they reflected upon their design expertise, which helped to improve their skills. Similarly, students could assess their design collaboration skills using the conversation analysis and reflective practice analysis described in this paper.

5.3. Limitations, contributions, and further research

This study was set up as an exploration of the concept of design collaboration skills. By using an interpretive analysis and by staying close to the data, we were able to characterise the processes of sharing and integrating design knowledge at different levels of design expertise. This study contributes to the advancement of the social perspective on design (Bucciarelli 1994, Stumpf and McDonnell 2002) by conceptually disentangling the concept of design expertise and collaborative design skills.

Our study, however, also has several limitations. First, it is probable that the findings are influenced by the particular design education that the students in our study were exposed to. The degree programmes from which we recruited the bachelor and master students incorporate a substantial amount of teamwork, but the courses have only recently started to explicitly address social skills. This means that the master students in our sample were not novices to design collaboration, but had perhaps only reached an incipient stage of understanding how to design collaboratively.

Second, the field study is based on a small sample size as a result of the time-consuming in-depth qualitative analysis. Therefore, the findings cannot be empirically generalised (Yin 1994). Use of the Kantjil Design game to simulate design could have influenced the results as well. A validation study with clear metrics for design expertise in a different educational setting with a larger sample size using a different design task would be desirable to address these limitations.

Third, team familiarity may have been a confounding factor in this study: the professional teams not only were most experienced as designers, but also had spent much of their time collaborating together. Research on group development generally shows that team members first need to establish forms of group co-ordination before they reach their best performance level (Gersick 1988, Arrow et al. 2000). Hargadon and Bechky (2006) showed that collective moments of creativity happened when people knew and trusted each other to ask for help, which would suggest that the professional teams in our sample were probably better prepared for design collaboration than the student teams. In addition, Wetmore et al. (2010) found that group familiarity impacted some but not all dimensions of team performance in a design review meeting. To avoid such confounding factors, our study would need to be replicated with ad hoc teams who have no previous experience in designing together.

Fourth, we employed different forms of recruiting participants: some were recruited as part of a course and others through contacts to professional design firms, and one team was paid for participation. These could have influenced the results, although neither the post-simulation discussion and survey nor the analysis of the team process indicated that they did. However, for the replication study, the form of recruitment should be the same for all types of teams.

The contribution of our research lies in advancing the understanding of collaborative design in different ways. First, we applied two methods (Valkenburg and Dorst 1998, Stumpf and McDonnell
M. Kleinsmann et al.

that were developed within the design research community, which to date have not been applied to a plurality of empirical settings. Valkenburg (2000) found preliminary evidence that the extent to which teams behave as ‘reflective practitioners’ is related to their performance. The present study found mixed evidence concerning the relation of the displayed reflective practice behaviour and the level of design expertise. In our study, advanced learners, the master teams, performed worse compared with the less experienced novices, the bachelor teams. To further advance the method of reflective practice, the discriminatory value of this analysis method must be further investigated in larger samples.

Second, we combined the methods of reflective practice coding as proposed by Valkenburg (2000) with the rhetoric analysis of dissociation and association as proposed by Stumpf and McDonnell (2002) and found that these two methods support each other. We used the theory of collective cognition proposed by Gibson (2001) to propose a typology of design collaboration skills, which could provide a fruitful theoretical base for further research.

Past research focused on either the nature of design expertise (e.g. Ball et al. 2004, Lawson 2004, Lawson and Dorst 2009) or collaboration processes in general (e.g. Valkenburg and Dorst 1998, Kleinsmann and Valkenburg 2005, Ostergaard and Summers 2009). The present study added a sub-category ‘design collaboration skill’ that is partly related to design expertise and to general collaboration skills. Past studies on collaboration in design provided us with the suggestion that the level of knowledge integration and the quality of this integration play an important role in the development of design collaboration skills. With this study, we could only identify three distinct stages of collaborative design expertise. Future research could draw on our conceptualisation of design collaboration skills and develop a reliable coding scheme that is applicable to different contexts and investigate the discriminant value of the proposed levels of design collaboration skills. In addition, further research could elucidate how design collaboration skill and general collaboration skills are related and develop over time.

Finally, the typology proposed by Lawson and Dorst (2009) concerning the levels of design expertise was based on Dreyfus and Dreyfus’ (2005) model and on their own observations of design behaviour and interviews with many designers. In the present study, we found that the levels of their typology were indeed observable in design teams. However, it would be valuable to operationalise the typology of Lawson and Dorst to provide reliable metrics for design expertise. To do that, further research must establish more precisely the constitutive elements of expert design behaviour and formulate operational definitions for each element. With clearer metrics for design expertise and collaborative design expertise, it would be possible to establish if there is a congruency between Lawson and Dorst’s (2009) model and the stages of collaborative design expertise.

In spite of the above-mentioned limitations, we believe that the theoretical insights concerning the nature of design collaboration skills derived are not limited to the specific context and sample studied. Research in other disciplines corroborates our findings that design expertise and collaborative design skills develop independently: studies on social skills in the context of aviation, offshore drilling, and medical teams showed that domain expertise and context-specific collaboration skills (Salas et al. 2001, Reader et al. 2006) have demonstrated that being a domain expert is not sufficient for addressing complex situations in a team. These studies also found that the ability to share and integrate knowledge needs to be developed in dynamic team settings either on the job or in simulation-based training as the one used here.

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Note


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