International Conference on Research into Design, ICoRD'09

Novice-Expert Design Consultations: Findings from a Field Study

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Keywords: design expertise, knowledge creation, discourse patterns

Abstract

This study aimed to investigate the process of novice-expert consultation meetings in an organizational context by identifying phases of the discourse and analysing the nature of these phases. An empirical study was performed at Rolls-Royce Aerospace Engineering by capturing 7 audio-records of meetings between trainees (novices) and expert designers over the course of the design projects of 3 teams of trainees. 3 main phases, *context sharing*, *knowledge creation* and *information seeking*, were distinguished and it was found that these phases alternated often during consultation meetings. Furthermore, over the course of trainees' design project, the length of the knowledge creation phases increased while the length of information seeking phases decreased and the length of the context sharing phases remained the same. Finally, the different roles of expert and novice are discussed and suggestions for further research are provided.

1 Introduction

Acquiring product and process information during the design process is critical for the design outcome, since this information influences the successfulness of the design outcome [1, 2]. Therefore, design engineers spend a significant part of their workday acquiring information [3, 4]. Previous research showed that the majority of the information requests raised by design engineers were answered by asking other people rather than by consulting documents or other explicit forms of information [4]. In addition, [1] found that successful solution search occurred interacting with colleagues

and that inter-personal communication is the main prerequisite for satisfying availability of information.

Research on design expertise showed that experts tend to be better information gatherers and processors then novices [5], based on the following characteristic of expert design engineers. Firstly, experts by nature have more detailed knowledge than novices. Furthermore, they are also better in structuring and organizing their knowledge, resulting in the creation of integrative knowledge structures [6]. Finally, experts design engineers are good at applying their knowledge in different contexts [7]. These characteristics make expert design engineers better in knowledge creation processes.

Researchers from different fields agree that it takes up to ten years to become an expert in a particular field [5, 6, 8]. Considering the time it takes to acquire design expertise and its importance, industrial companies have an interest in accelerating the process through which expertise is acquired. One method to speed up this process is to provide the novice design engineer with hands-on experiences of company experts [9].

This study focused on the interaction process between novices and expert design engineers during consultation meetings, and in particular on the different phases that occurred. This paper firstly presents a literature review about novice-expert design interaction and secondly reports an empirical study.

2 Novice-expert interaction in design

[10] interviewed experts involved in a design project with the aim of understanding what responsibilities they felt during interactions with novices. They found that experts had seven different responsibilities: 1) knowledge sharing; 2) process reference; 3) filling the gaps; 4) process improvement; 5) gaining social acceptance; 6) solution creation; and 7) tool utilization. Although these responsibilities show a particular characteristic of a novice-expert consultation, this study does not actually show how experts interact with novices in order to fulfil their responsibilities.

An investigation that shed light on the interaction between expert and novice designer was the study of [11]. The authors studied novices involved in a knowledge acquisition project in the aerospace industry with the aim to understand the novices' knowledge needs. By analyzing the questions and statements that teams of novices posed to experts, they found that the knowledge needs of novices can be classified into 11 classes: 1) obtaining information; 2) typical value; 3) terminology; 4) trade-offs; 5) how does it work; 6) why; 7) what issues to consider; 8) when issues to consider; 9) how to calculate; 10) design process; and 11) company process. In addition, the answers provided by experts were also analysed and classified to develop an understanding of the interactions. Analysing the above classification it seems that questions and statements asked by novices are predominantly aimed at querying existing bodies of knowledge. As this study was executed in the context of a knowledge acquisition project, which could have influenced the generalisability of the results.

This review showed that the current understanding of novice-expert interaction in design is still limited. The focus of previous research was either on elements not directly related to the interaction, e.g. experts' responsibilities, or on isolated elements of the interaction, e.g. novices' questions and statements, rather than on the complete conversation. As a consequence the results often fail to describe the evolution and manner of functioning of novice-expert consultations. Another observation is that the variation of

novice-expert consultations over the course of the design process was neglected in previous studies. Therefore, it is unknown how the interactions and their associated behaviours change over time.

From a methodological perspective, previous research was either based on a retrospective means for data collection, e.g. [10] used interviews, or on direct means, e.g. [11] used audio-recording. In addition, the experts interviewed by [10] undertook real design projects. Whereas, the consultations studied by [11] were not related to design projects and therefore, the novices might not have been properly motivated.

To overcome the limitations of the discussed studies, and to take a more comprehensive view on the novice-expert interaction, the researchers decided to undertake empirical research that met the following criteria:

1. Focus on the complete interactions
2. Focus on the entire design process
3. Focus on design tasks in an organizational organisation
4. Use direct means of data gathering

2.1 Methodological approach

The research approach consisted in undertaking a field study, with an ethnomethodological perspective, to capture naturally occurring novice-expert meetings as part of the novice's design project in an organizational setting.

The training program at Rolls-Royce Aerospace Engineering, setup for engineering gradates, provided an opportunity for data collection. The Design & Make project, which is part of the training program, is a design practice in which the trainees (novices) worked on highly technological projects in groups of four, for clients inside the company. During data gathering, the first author followed three teams of trainees, who completed two previous placements of three months in different departments of Rolls-Royce. As the novice-expert consultation meetings were naturally occurring during the course of the trainee's design project, the participants in this research can be considered properly motivated to get the most out of a consultation meeting.

The aim was to collect meetings in the different project stages in order to collect a sequence of meetings. Therefore, the researcher collected consultation meetings for seven weeks, during the entire design process of the Design & Make project. For this study seven meetings were analysed. In the followed meetings, the novices consulted different experts. The main means for capturing the novice-expert consultation meeting was an audio recorder. The gathered meetings were transcribed.

Since the ethnomethodology paradigm rejects an a priori coding scheme and normative frameworks, a coding scheme was inductively developed from the data [12]. The data was coded using NVivo, a CAQDAS software tool to support qualitative analysis. The final coding scheme characterised the process of the novice-expert discourse.

3 Results

This research aimed to gain insights in the process of experts' consultation by novice designers. As discussed in the method section, the researchers analysed the entire meetings to identify distinct phases.

This section starts by describing the characteristics of the collected meetings. After this, the key phases of the consultation meetings, as identified during data analysis, are presented and explained. The distribution of the phases in the individual meetings is presented, and the phases' alternation is illustrated. Finally, the meetings are grouped by the stage of the design process in which they occurred to investigate how the phases changed over time.

3.1 Data set description

Table 1 shows the characteristics of the seven analysed meetings. The meetings are not ordered according to sequence of collection but the ordering follows the stages of the design process [13]. For the purpose of this research *embodiment design* was integrated within the *detailed design* phase. From Table, 1 it can be seen that two meetings took place in the task clarification phase, three in the conceptual design phase and two in the detailed design phase.

Table 1 Meeting characteristics

Meeting	Team	Design stage	Number of words	Duration
1	B	Task clarification	11709	01:07:24
2	A	Task clarification	7698	00:39:30
3	A	Conceptual design	9932	00:54:06
4	B	Conceptual design	8000	00:43:08
5	B	Conceptual design	8539	00:50:06
6	C	Detailed design	3520	00:27:41
7	C	Detailed design	9771	01:01:01

3.2 Consultation phases

Analyzing the data to understand the interaction between novices and experts, three main phases of a consultation meeting were identified. Next, the phases will be presented and discussed by showing their characteristics:

1. *Information seeking*
   This phase consists of seeking past product and process information, e.g. procedures and design rationale. Explicit questioning is often employed by the information seeker, e.g. *"Is there a standard [transport] case you usually buy in for this kind of thing [the measurement device]?"* and *"Do you know why this little thing is here [pointing to a past design]?"* The discourse is simple and consists of sequences of questions and answers.
2. *Knowledge creation*
   This phase consists in developing new design knowledge, e.g. generating ideas and analysing solutions. Little questioning is generally employed in knowledge creation. The discourse is often elaborated and rich of arguments, e.g. in episode presented below, the expert (E1) reasons about the behaviour of the concept as presented of by the novices (C and D):

   E1 The difficulty you might face is the mechanism for traversing up and

down and across.

C Yeah.

E1 Because you're going to have to do that – I don't know; you're going to have to do that using some sort of an electric motor or something.

D Yeah.

E1 You can't have the user doing that.

D No.

E1 Because it's not going to be consistent enough.

D Yeah.

E1 And then your fixture and your device starts to become nightmarishly

3. *Context sharing*

This phase consists in sharing contextual information, e.g. job title, personal experience, job background and project background. Explicit questioning is seldom used by the information sharer. However, more often the information is spontaneously introduced in the conversation. The discourse consists of long conversational turns and therefore is not interactive, e.g. the explanation presented below in which the novice introduces himself, the problem and states what his interest is for that particular meeting:

M Just to tell you a bit about the background of this. There are four of us working on a Design & Make graduate program. And we've been asked by some engineers from the [department] design a gearbox. Which is like a concept that was invented by someone in [department]. Which is being patented. And in this sort of gearbox, we've got this part [referring to drawing], which is driving a cage which is placed into a laminated element. The aim of this mission is to have a gear ratio of [specific value] between entry and exit. And basically what I'm looking for at this stage is some advice from experienced people regarding bearing design.

Table 2 shows the distribution of the three phases in the seven meetings. The duration of the individual phases was estimated based on a word count, not time. The assumption is made that word counting reflects the time spent in a certain phase by the participants to a meeting. A variation in the duration of the phases is noticeable and can be explained by the fact that the meetings were captured during different stages of the design process. Overall, these results showed that *context sharing* (49%) and *knowledge creation* (43%) were dominant in the meetings, with *information seeking* (8%) having only a marginal role. This implies the importance of context sharing in the course of the consultation meeting. Considered that context sharing is a substantial part of a conversation in a consultation meeting, the interesting result is that the novice-expert interaction is more aimed at applying the expert's knowledge, during knowledge creation, to develop the design rather than acquiring past product and process information.

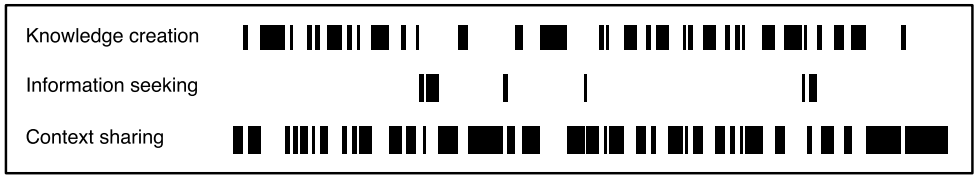
Although the results presented so far may suggest that each consultation phase in a meeting evolved continuously, data analysis showed that the phases were fragmented and alternated.

Table 2 Overview of phases per meeting

Phase	Meetings							Average %
	1	2	3	4	5	6	7	
Context sharing	55.7%	44.2%	58.1%	34.6%	47.7%	56.5%	47.7%	***49%***
Knowledge creation	19.9%	17.1%	4.4%	3.3%	0.2%	6.4%	1.4%	***8%***
Information seeking	24.4%	38.7%	37.4%	62.1%	52.2%	37.1%	50.9%	***43%***
Total	100%	100%	100%	100%	100%	100%	100%	100%

In order to illustrate this characteristic of the meetings, one meeting was selected. Figure 2 shows the alternation of the consultation phases for meeting 5, which was organised by team B and took place during the conceptual design stage. An example a particular alternation is presented next.

Figure 1 Overview of phase alteration



Team B worked on a project to develop a new design for a vent pipe restrictor, a feature aimed at controlling the venting of air out of the bearing chamber in a gas turbine. This feature needed redesign because, as a consequence of the undesired venting of oil droplets, oil lacquers can break off from the wall pipes and block the restrictor. A key issue in this project was designing a test rig to evaluate the newly proposed vent restrictor designs. Two segments of the transcript from this meeting, coded with the different consultation phases, are now presented to illustrate the phases' alternation.

[CONTEXT SHARING]

D And our problem is to actually somehow get the sugar solution kind of either nebulised or atomised -

E Yeah.

D And then spray it down as a mist inside the pipe and I guess the finer it is, the easier it's going to - or the quicker to drive but the finer the mist, the smaller the particles, the easier it's going to kind of coat the outside of the tube and actually create some sticky residue there for things to stick to.

[KNOWLEDGE CREATION]

E You used the word solution there.

D Yes.

E And I guess you - we're starting off thinking about oils and liquids.

D Yeah.

E And I was just thinking about could we use a sticky powder; something like you know, seaside rock ground up into flakes like a solid sugar?

D Well,

E That's like - and then dampen -

D ah!

E it slightly.

In the fragment, a member of team B shared with the expert contextual information on a previously generated design option, i.e. using a sugar solution to replicate the oil-air mixture, as well as the subsequent issues that the team faced, i.e. nebulising the sugar solution and spraying it over. The interesting pattern here is that during the conversation the novices shared the nature of their problem and the expert is trying to solve their problem by proposing a solution. This example shows how the expert contributed to the novice' design project during a knowledge creation phase.

In order to gain a deeper understanding of the phases' alternation, the researchers analysed the data to understand who the initiator of each new phase was. Table 3 describes the frequency with which the novice or the expert initiated a new phase. The novices initiated two thirds of the context sharing phases, whereas the experts initiated the same proportion of knowledge creation phases. The novices always initiated information seeking phases, as they reflect explicit requests for information to progress design tasks and therefore can only be posed by the novice.

Table 3 Overview of phase initiator

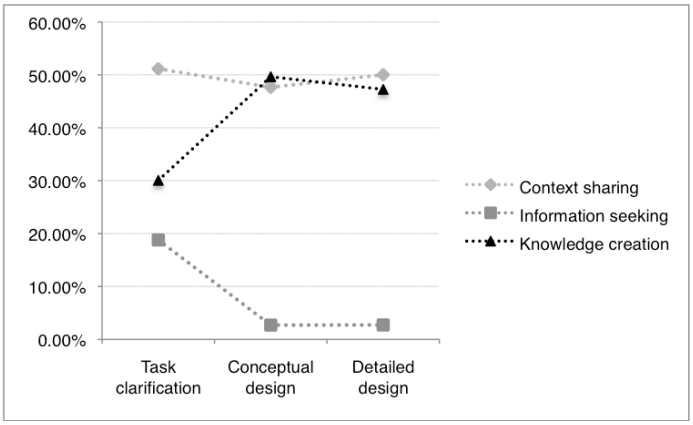
	Context sharing	Knowledge creation	Information seeking
Novice initiated	66.7%	31.6%	100%
Expert initiated	33.3%	68.4%	0%
Total	100%	100%	100%

When qualitatively analysing the initiation of the context sharing phases, it was found that the novices most often started a context sharing phase by expressing a statement, whereas the experts often started by posing a question to the novice. Furthermore, the experts initiated the knowledge creation phases often by proposing a solution, whereas the novices by evaluating the applicability of a previous discussed solution.

3.3 Consultation phases along the design process

Figure 1 shows the variation of the consultation phases during the design process. *Information seeking* (squares) decreased with the development of the design project. Therefore, the more the product is defined the less time novices spend with experts to seek information. *Knowledge creation* rarely happens during the meetings early on in the design process. It is expected that at this stage of the design process the novices do not engage in knowledge creation with the experts because they still have little project understanding. However, in conceptual design, much time is spent on knowledge creation. Finally, in detailed design, knowledge creation still has a significant role. *Context sharing* is the only phase that does not change over the design process. In this context it is noteworthy that six out of seven meetings were with experts that the novice had not previously met. One was a follow-up meeting, meeting 4 from Table 2, with a previously consulted expert. It was found that in that meeting, the least time was devoted to context sharing.

Figure 2 Phases distribution over the design project



4 Discussion

The aim of this research was to identify the process of information gathering during novice-expert consultations. Novice-expert consultation meetings can be seen as opportunities for novices to acquire useful information and to collaboratively create new knowledge about design problems.

The results showed that in particular context sharing and knowledge creation phases occurred often during novice-expert consultation meetings. The information seeking phases accounted only for a small percentage of the complete meeting. The difference between these findings and those of [11], might be caused by the fact that in this research, meetings were observed as part of real design project. Therefore, the results emphasis the importance of gathering research data from real design projects in design practice.

Furthermore, the findings showed that the phases in the meeting alternated often and that the novice and the expert initiated different phases. Therefore, it appeared to the authors that the expert and the novice had different roles during the consultation. Next, the roles of the novice and the expert during the three identified phases are considered

and reflected upon and is presented in Table 4.

It was found that experts contributed to the novice's design task by providing both design knowledge and design experience. The first is aimed to fill in the information gaps of the novices and the second is aimed to use the expert's experience as a resource for creating new knowledge about the design. Furthermore, increasing the expert's understanding of a problem is a key task for novices to enable the interaction with an expert. Only by sharing context information, the information provided and the knowledge created by the expert will fit to the specific problem faced by the novice.

Table 4 Roles of expert and novice designer per phase

Phase	Context sharing	Knowledge creation	Information seeking
Expert role	Explaining organizational procedures and job characteristic of the expert *to increase awareness at the novice side on what the novice can expect from the expert*	Applying the expert's knowledge on the design problem of the novice *to develop the design*	Providing information to the novice by responding to explicit information requests, *to support the novice's information needs*
Novice role	Explaining the design problem and context *to increase the expert's problem understanding*	Implementing explicit information provided by the expert during the conversation on the novice's design problem, *to develop the design*	Requesting explicit information to the expert *to fill the information gaps of the novice*.

Based on the differences in contribution of the expert and the novice, the importance of taking into account both the novice's perspective and the expert's perspective when analyzing novice-expert interaction is shown. Therefore, a recommendation for further research is to focus on the *interaction* between novices and experts.

Concluding, this study showed that the novice-expert interactions could be considered highly complex. However, it also showed that by unravelling phases, roles and characteristics of the meetings in general, structures and relations appear that can help practitioners by increasing their understanding of elements in the conversation that are of importance to facilitate the consultation meeting.

In this study seven meetings were analysed. In order to strengthen the results of this research further data collection and analysis is required. The results are based on data collected from novice designers working on engineering design tasks in the aerospace sector. Therefore these findings can only be generalized if they are confirmed with other data sets.

Further research is required to develop a deeper understanding of the specific activities occurring in the different consultation phases and how these activities collaboratively happen. Therefore, the authors will continue investigating novice-expert interactions to address the suggestions for further research as presented above.

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