Interviewing as a method for data gathering in engineering design research

Abstract

The objective of this paper is to present a set of recommendations for conducting and reporting on interview based engineering design research. These recommendations are informed by a review of publications in *Research in Engineering Design* that rely, at least partially, on information and perspectives collected through interviewing in addition to the personal experiences of the authors and their students. These recommendations focus on operational steps that can be taken to improve and increase the confidence associated with this form of qualitative research. Specific emphasis is placed on the reporting of details associated with the interview. Finally, recommendations are presented to the research community in order to advance the acceptance and objectification of the interviewing in case study research.

Keywords: *case study research; interviewing; qualitative research*

1 Motivation: The Need for a Systematic Approach to Interviewing as a Method for Case Study Design Research

It is widely recognized that the study of engineering design practice is essential for the development of effect tools, methods and processes for industry and for informing engineering education. The mechanisms that are available to support this study vary with respect to the objective of the research (to test hypotheses, to find evidence, to find challenges and opportunities, to build theories) and with respect to scope of study (complete design project, a design method or tool, an atomic design activity). One popular research approach that is empirically grounded is case study research (Yin 2003, Teegavarapu *et al.* 2008), which is focused on understanding complex phenomena within a real context. This approach to studying engineering design seeks to answer questions about why and how things occur through discovery of patterns or counter-patterns in objectively collected data and information. Case study research includes different methods such as document analysis, participant as

observer reflections, ethnographic studies, and interviewing. This paper specifically explores the research method of interviewing, both from the perspective of designing and conducting interviews to reporting the interviews (Yin 2003, Creswell 2008).

Case study analysis, interviewing, and other qualitative research methods are sometimes challenged in the engineering design research community with four primary objections. We present these objections and a set of responses in order to provide justification for the recommendations that will be made throughout this paper to aid researchers in communicating their research (Teegavarapu *et al.* 2008).

- *Generalization from a single or limited case set*. The traditional scientific approach to inquiry, based on replicative logic, seeks patterns of behavior repeated many times to have great confidence in the repeatability. This is the purpose behind experimentation to develop and then test theories. These experiments are bounded as external variables are controlled as much as possible with the aim to widest possible clearly provable scope of the model or theory. Case studies are based on the principle of falsification logic where if a theory is not true for one case, then it is not generalizable (George and Bennett 2005). Thus, case studies can be used efficiently to find single cases to disprove theories, but care must be given to the selection and the contextualization of the case. Thus, the objection can be addressed through careful selection of the case and intentionally seeking out patterns to falsify the theories.
- *Lack sufficient rigor*. The methods employed are uniquely designed for each case context and adapted to the specific contexts. This introduces a challenge for the researcher as they are compelled to justify the research process, validating the steps employed. This form of qualification is essential to case study analysis, but is often not seen as critical for quantitative studies as experimental and simulation studies as the research methods for experimentation work are often well defined and canonically accepted in the community. One of the most powerful approaches to address this qualification of the process is to be thorough and detailed in the reporting (Yin 2003, Dain *et al.* 2013).
- *Overly easy to bias the results.* This potential for bias is also found in the traditional scientific method as researchers might only report the findings that support their models or

that they design the experiment to test only that which is sought (McComas 2002). The most common approach to addressing this is through scientific transparency exposing all the conditions, issues, variables, controls, and interventions that are associated with the study. With case study analysis, an additional layer of quality control is introduced as the research principle is based on falsification logic. As the researcher actively seeks to disprove the hypothesis, all efforts are made to find evidence from different perspectives that counter the hypothesis (Flyvbjerg 2006). This triangulation and transparency combine to mitigate the potential for bias in case analysis.

- *Spans too great a time to support validation*. As case research involves a deep study of a complex process involving many individuals and other participants, the time needed for data collection and analysis can be quite extensive when compared to other empirical and experimental research approaches (Yin 2003, Teegavarapu *et al.* 2008). Moreover, the subject of study for case study in engineering design tends to be complete or partial design processes, rather than a single design tool or activity. That said, this is an operational objection that might influence a researchers choice of approach, but should have no bearing on the conclusions drawn from the case study.

These objections can be addressed through both systematic planning and objective reporting of the findings. Thus, this paper presents issues that are critical to designing and executing interviews based on the experiences of the authors in conducting interviews. Moreover, a discussion is presented on reporting the interviews with a specific focus on addressing the objections suggested above.

This paper is based on the experiences of the authors in conducting engineering design research by employing interviews as research instruments across several years and varied projects. Eckert has used interviews as her main research tool to gain understanding of different design phenomena to identify and explicate the needs for new tools and methods. Summers has primarily employed interviews as triangulation tools to validate, corroborate, and verify research finds based on industry behavior patterns. These corroboration interviews are more tightly constructed and analyzed than Eckert's more open-ended discovery studies. This dual perspective will be discussed through the paper, highlighting the common practices for the

different research objectives while discussing the impact that the research goals have on each step of the interview tool development and use.

As such, this paper discusses how to conduct interviews from a pragmatic, operational perspective, covering issues with which we have experienced, discussed, and struggled over the years with our own graduate students and researcher colleagues. We also draw on the lessons we have learned from reviewing interview-based research papers. The paper's focus lies on designing and executing interviews. While we will touch briefly on the analysis of interview data, this is not the main aim of the paper as it is extremely contextually dependent on the individual needs of the researcher. Thus, we offer, through this paper, a general guide for engineering design researchers when considering to deploy interviews in their own research.

The next section presents a review of those articles in *Research in Engineering Design* that present research employing interviewing as a method of inquiry. This review suggests that there are many dimensions of reporting interview based research that could be strengthened to improve the objectivity and confidence of the work. This is followed by a discussion on how to employ the interview research method. This approach begins first with defining the context and then designing the interview. Executing the interview, post interview activities, and finally general best practice observations are provided in the following sections.

2 Interviewing in Engineering Design Research

In order to understand where challenges, limitations, and opportunities lie in terms of using interviews to support engineering design research, we examine papers of researchers reporting on their use of interviewing. This review is undertaken to provide context and a broad understanding of the role that interviewing currently plays in engineering design research. This is not intended to provide definitive proof in support of or in contrast to interviewing and the different roles and information reported.

Initially, 68 articles were retrieved from the RED on-line database based on a single word query: "interview". We concentrated on one journal to provide a broad view of how interviewing is used and reported as a research tool in research on engineering design. This review is not intended to be a comprehensive analysis of interviewing. These articles were then

reviewed individually to determine whether the discussion on interviews expressed the interview as a research tool to gather data and information to analyze or whether they were discussing interviews as part of a design tool. For instance, in (Cardin *et al.* 2012), the authors discuss interviews as a component of a guided ideation tool that is evaluated through a controlled experimental study. This paper was not included in the interview analysis as it was not using interviewing as a research tool. After this initial analysis, 30 papers remained. These papers ranged from 1997 through 2013.

Table 1 illustrates the stated purpose of the interview, the purpose of the research study, additional research methods employed in the study, and a general description of the domain of the interviewed subjects. The purpose of the research study is defined as either seeking an understanding of a phenomena or the development of a tool for design support. The tool development could be in the requirement definition, implementation, or testing stages. It is clear that interviewing can be used for both problem finding or understanding and for solution support or tool development. The purpose of the interview, within each research study, was defined to be core, verification, motivation, explanation, or evaluation. If the interviewing is the primary research method for data collection in the research study, then it is defined as "core". If interviewing is used to triangulate information and inferences drawn from other sources, this it is considered to be primarily being used for verification. In one study, it appears to be that the interviews are used to form the motivation for the research study; highlighting the challenges that are found in industry that might be addressed with the proposed tool (Achiche *et al.* 2013). In three cases, it appears that the authors' intent for employing interviews was to identify explanations of anticipated and observed behaviors (El-Tayeh *et al.* 2008, Kloss-Grote and Moss 2008, Legardeur *et al.* 2010). This explanation was secondary to the other research methods that might be employed within the research study. Finally, three papers used the interviewing research method to support an evaluation of a proposed tool (Eppinger *et al.* 1997, Kloss-Grote and Moss 2008, Keraron *et al.* 2009). The various authors employed interviewing for a variety of purposes that are not exclusively aligned with the purpose of the research study, suggesting that this research method is flexible and elastic as it can be structured to support many research needs. Further, each paper was

examined to determine what additional empirical or simulation (Dain *et al.* 2013) research methods were employed to support the study goals. There does not appear to be a clear pattern in terms of what types of research methods (Teegavarapu *et al.* 2008) are paired with interviewing. Rather, what appears to be popular with the researchers is a triangulation across these various methods to, perhaps, help build confidence in the research approach. Finally, the application domain and context of the interviewees and processes studied were extracted from the papers. There appears to be a general trend that interviewing is used to explore and understand product development activities of fairly complex systems, such as automotive, aerospace, highly integrated electronics, production systems (gas production and oil rigs), or large industrial equipment (capital goods). While a few examples are found for moderate to simple product domains, these are typically associated with academic or student design projects that are studied from an educational perspective. Generally, it appears that interviewing is useful for understanding complex systems that are not easy to simulate or that include many different stakeholders, actors, and systems.

Table 1: Interviewing as a Research Method (Study Purpose, Interviewing Purpose, Additional Methods Employed, and Context of Study)

Citation	Purpose of Research Study	Purpose of Interview	Additional Research Methods	Context of Study
(Aurisicchio *et al.* 2013)	U	V	E & Y & O	A
(Achiche *et al.* 2013)	T	M	M, Q	unreported
(Veldman and Alblas 2012)	U	C	D	Q
(Shankar *et al.* 2012)	U	V	D	U
(Ahmad *et al.* 2012)	T	V	M	E
(Vianello and Ahmed 2012)	U	C		G
(Rexfelt *et al.* 2011)	T	V	X	U
(Pasqual and De Weck 2012)	T	V	M	E
(López-Mesa and Bylund 2011)	U	C	O	U
(Jagtap and Johnson 2011)	U	C	D	A
(Tribelsky and Sacks 2010)	T	V	D & O	C
(Legardeur *et al.* 2010)	U	X	E	U
(Eckert and Clarkson 2010)	U	C	E	A & U
(Wasiak *et al.* 2010)	U	V	D	X
(Keraron *et al.* 2009)	T	E	D	A & G
(Romero *et al.* 2008)	U	X	M	F
(Kloss-Grote and Moss 2008)	T	X & E	D	A
(El-Tayeh *et al.* 2008)	T	V	X	unreported
(Reymen *et al.* 2006)	U	C		M, S, R (acad)
(Donaldson 2006)	U	C		Highly mixed (simple)
(Demian and Fruchter 2006)	U	C	E	C
(Almefelt *et al.* 2006)	**U**	**C**	**D**	**U**
(Zika-Viktorsson and Ritzén 2005)	U	C		U & Q
(Gil *et al.* 2004)	T	U	D & M & O	C
(Eckert *et al.* 2004)	U	C		A
(Beskow and Ritzén 2000)	T	C		F
(Newstetter 1998)	U	V	E	M (acad)
(Cross and Cross 1998)	U	V	P	U
(Eppinger *et al.* 1997)	T	E	M	F
(Ehrlenspiel *et al.* 1997)	U	V	V & D	M (acad)

Purpose of Study: U = Understanding; T = Tool
Purpose of Interview: C = Core; E = Evaluation; M = Motivation; V = Verification; X = Explanation; U = Unclear
Additional Methods: D = Document analysis; E = Ethnography; M = Modeling; O = Observation; P = Protocol Analysis; Q = Questionnaire; V = Video; X = Experimentation; Y = Diary
Context: A = Aerospace; U = Automotive; M = Mechanical; F = Manufacturing; G = Gas; C = Construction; E = Electronics; Q = Equipment; S = Software; R = Architecture; X = Complex Systems

These papers were also interrogated to understand the trends associated with what information is presented to describe the stakeholders in the interview process. Recognizing that the interview is essentially a conversation between the researcher, or the research team,

and the selected representative from the organization being studied, one can see four dimensions that could be reported and described: the organization(s), the interviewee(s), the interviewer(s), and the pre-existing relationship between the interviewer and the interviewee. These information elements, as reported in the papers identified, are found in Table 2.

Table 2: Interview Participants (organization, interviewee, interviewer, and pre-existing relationships)

Citation	Organization	Interviewee	Relationship between interviewer and interviewee	Interviewer
(Aurisicchio *et al.* 2013)	1 company	10 engineers (average experience, and SD provided)		
(Achiche *et al.* 2013)	5 different companies, but domain unknown	5 managers & (minimum of 8 years in PD)		
(Veldman and Alblas 2012)	2 companies different industries (Gas and Machinery)	11 formal (managers, engineers, design, manufacturing, purchasing, maintenance) & 30 informal (managers, engineers, etc.); REPORTED in TABLE		
(Shankar *et al.* 2012)	1 company	6 engineers + 1 manager (details presented in table)	Employee	S
(Ahmad *et al.* 2012)	Single	1 manager + 1 engineer & Group discussion		
(Vianello and Ahmed 2012)	4 instances (oil rigs) for one company	18 interviews; Table provided		
(Rexfelt *et al.* 2011)	Automotive OEM; Traffic Control; University	10 participants from experiment	Coach	
(Pasqual and De Weck 2012)	Single	1 lead systems engineer		
(López-Mesa and Bylund 2011)	Single company	Phase 1: 20 individual sessions (1 pair session; Reported in table) & Phase 2: 11		S
(Jagtap and Johnson 2011)	Single	3 designers		S
(Tribelsky and Sacks 2010)	Multiple companies/projects	8 project leaders & 3 client reps & 3 design leaders	affiliation gave access	
(Legardeur *et al.* 2010)	Primarily 1 company (and partners)	Multiple (exact number unknown)	"partner" – joined the company	
(Eckert and Clarkson 2010)	Multiple companies, multiple domains	18 + 2 additional case studies		S & P
(Wasiak *et al.* 2010)	Single	Multiple (different roles)		
(Keraron *et al.* 2009)	2 companies (different domains)	30 maintenance – aerospace & Unknown – gas		
(Romero *et al.* 2008)	5 enterprises (different departments within)			
(Kloss-Grote and Moss 2008)	1 company (3 projects)	6 (3 managers and 3 engineers)		
(El-Tayeh *et al.* 2008)				
(Reymen *et al.* 2006)	12 case studies (4 in software, architecture, mechanical)	2 junior+2 experts for each discipline (12 total)		
(Donaldson 2006)	20+ firms and 30+ enterprises	Number unknown: engineers, designers, artisans, fundis, students, faculty, NGO, government		
(Demian and Fruchter 2006)	1 main + four others (same discipline0	Engineers (unknown); Architect, engineer, manager		

Citation	Organization	Interviewee	Relationship between interviewer and interviewee	Interviewer
(Almefelt *et al.* 2006)	**Supply/design chain**	**Unknown (24 interviews with 25 people); Engineers, managers, purchasing, etc.**	**Previously worked on project**	**P**
(Zika-Viktorsson and Ritzén 2005)	5 companies, different domains	14 upper level & 40 project		
(Gil *et al.* 2004)	Unknown	Senior (22: engineers, 10: customer reps, project managers)		
(Eckert *et al.* 2004)	1 company	22 senior designers		
(Beskow and Ritzén 2000)	4 companies	30 used (from 78 collected); Varied hierarchies and functions		
(Newstetter 1998)	1 class, multiple teams	Unknown (at least 4 students; 1 prof.)	Team member	S
(Cross and Cross 1998)		1 designer		
(Eppinger *et al.* 1997)				
(Ehrlenspiel *et al.* 1997)			Teacher	

Interviewee: S = Single; P = Pair; T = Team

We have highlighted the paper on supply/design chain research study (Almefelt *et al.* 2006) as an exemplar of what and how to report the findings associated with the interview. Complete detailed reporting on the research steps employed in qualitative research is a powerful approach to address several of the concerns raised with respect to case study research mentioned earlier. Specifically, a communication challenge of design researchers using qualitative research tools is to convince the reader. Providing details addresses this challenge.

We also examined how the actual interview process employed is reported. The interviews location, the type of question ordering, the materials used during the interview, and the interview duration are aspects of the interview that might enrich the reader's confidence in the resulting inferences drawn (Table 3). For instance, the location of the interview is reported in eleven of the papers, with all but one of these (Achiche *et al.* 2013) reporting that the interviews were conducted in person, face to face meetings held at the organization's site. This might include meetings conducted in the interviewee's offices, conference rooms, or in the work place. The type of the interview conducted ranged from informal to semi-structured to

formal as reported in twenty of the reports. Of these, the majority of the interviews were self-reported as semi-structured, suggesting that there was a set of initial targeted questions that were used as the skeleton of the interview, but that additional questions, real time reordering, and clarifications were introduced to the interviews. Beyond the location and the type of question structuring, the duration of the interviews and the supplemental materials used or generated in the course of conducting the interviews inform the methodological approach used in this research method. Supplemental materials, ranging from audio recording to model building and verification, were only mentioned in the papers where this supplemental material was central to the research. The duration of the individual interviews, useful in providing an understanding about the depth and scale of investigation, is rarely mentioned in the papers, explicitly stated only ten times.

Table 3: Interview Process Details

Citation	Interview	Type of interview	Supplemental Material or Recording	Duration Interview (minutes)
(Aurisicchio *et al.* 2013)	In context (during work activities by a "shadow")	M	Audio	
(Achiche *et al.* 2013)	Company office & video conference	M	Table (form) to complete	
(Veldman and Alblas 2012)	On site	M & I	Post interview transcript coding in MS Excel	
(Shankar *et al.* 2012)	On site	M	Populated matrix was refined during interview	
(Ahmad *et al.* 2012)		I	Discussion included a refined model in the new tool	
(Vianello and Ahmed 2012)	Company site	M	Audio recording	15-45
(Rexfelt *et al.* 2011)		I		
(Pasqual and De Weck 2012)				
(López-Mesa and Bylund 2011)	Phase 1: On-site ("separate") & Phase 2: On-site ("on the go")	S & M	Audio recording and transcription	60-120
(Jagtap and Johnson 2011)		M	Audio recording	60-90
(Tribelsky and Sacks 2010)				
(Legardeur *et al.* 2010)		M	Actor Network	
(Eckert and Clarkson 2010)	On-site	M	Post interview reflections provided	30-120
(Wasiak *et al.* 2010)		M		
(Keraron *et al.* 2009)		M	Recorded/transcribed (200 pages text)	
(Romero *et al.* 2008)			Process diagrams to augment / inform the interview	
(Kloss-Grote and Moss 2008)		S	Classification tree	90
(El-Tayeh *et al.* 2008)		D		
(Reymen *et al.* 2006)			Evaluation sheet, Summary of previous interviews, Transcription	
(Donaldson 2006)				
(Demian and Fruchter 2006)	One site (office and construction site) & Off-site			60
(Almefelt *et al.* 2006)	On-site (relaxed atmosphere)	M	Piloted the interview; Transcript approval	60
(Zika-Viktorsson and Ritzén 2005)		M	Transcription	60
(Gil *et al.* 2004)		M	Follow-up interviews	60-120
(Eckert *et al.* 2004)	On-site	M	Questions evolved and subsequent interviewees validated previous	60
(Beskow and Ritzén 2000)	On-site	M	Different questions for each case, but some overlapping	
(Newstetter 1998)				
(Cross and Cross 1998)		I		
(Eppinger *et al.* 1997)				
(Ehrlenspiel *et al.* 1997)				

Type of Interview: S = Structured; M = Semi-Structured; I = Informal; D = Debrief

Again, only five of the researcher papers, including (Almefelt *et al.* 2006), present information in each of the four areas describing the interview. If other researchers would like to explore these topics through their own interviews as an external cross-case validation effort, information about the location of the interview, the type of interview, subsequent research tools employed, and the duration of the interview can be important to develop similar interviews. While interviewing can be highly flexible and adaptive, it is important to recognize that presenting as complete a perspective on the interviews as possible is useful to other researchers in their own work.

Next, while the objectives of the interviews, details of the interview participants, and explanation of the execution of the interviews provides the reader with a general context of the research tool, it is also necessary to examine the content of the interviews, such as the questions, answers, and summaries that are provided in the body of the paper (Table 4).

Table 4: Content of Interview

Citation	Questions provided	Answers provided	Summary provided	Discussion on the Interview Process	Country of Researcher
(Aurisicchio *et al.* 2013)				1	GB
(Achiche *et al.* 2013)				4	CA; IT; DK
(Veldman and Alblas 2012)	Y		Frequency Table	2	NL
(Shankar *et al.* 2012)	Y	Q	Yes (table and text)	7	US
(Ahmad *et al.* 2012)				1	GB
(Vianello and Ahmed 2012)	Y	Y	Analysis done and tested with Kappa agreement; Detailed results and tables	4	DK
(Rexfelt *et al.* 2011)		Y	Nominal	1	SE
(Pasqual and De Weck 2012)				<1	US
(López-Mesa and Bylund 2011)	Y	Y	Text and tables	6	SE
(Jagtap and Johnson 2011)	Y	Y	Yes	6	GB
(Tribelsky and Sacks 2010)				2	IL
(Legardeur *et al.* 2010)				1	FR
(Eckert and Clarkson 2010)				3	GB
(Wasiak *et al.* 2010)				1	GB; AU
(Keraron *et al.* 2009)			Text	2	FR
(Romero *et al.* 2008)				1	ES
(Kloss-Grote and Moss 2008)	A	Y		3	DE, GB
(El-Tayeh *et al.* 2008)				<1	AE; GB
(Reymen *et al.* 2006)	Y	S	Yes (body of paper)	9	GB
(Donaldson 2006)				<1	US
(Demian and Fruchter 2006)		Y		1	GB; US
(Almefelt *et al.* 2006)	Y	Y	Discussion	9	SE
(Zika-Viktorsson and Ritzén 2005)				9	SE
(Gil *et al.* 2004)				1	GB; US
(Eckert *et al.* 2004)				5	GB
(Beskow and Ritzén 2000)				11	SE
(Newstetter 1998)				<1	US
(Cross and Cross 1998)				1	GB
(Eppinger *et al.* 1997)				<1	US
(Ehrlenspiel *et al.* 1997)	Y			1	

Questions Provided: Y = Yes; A = Full question databank made available
Answers Provided: Y = Yes; S = Samples; Q = Direct Quotations

Again, there were few papers that presented details on these five descriptors, including (Almefelt *et al.* 2006). This paper presents a high level of detail on the interview process, establishing itself as a good exemplar for other researchers when considering how to structure

details of the research. By identifying this paper as a best practice, we hope to highlight to others how they might present their own work.

It is clear that the questions are not typically reported, with only eight papers reporting even example questions. Example answers and responses to these questions are only explicitly reported in nine papers. Finally, only nine papers provided a summary or synopsis of the individual interviews, either in tabular or textual form. It is clear that this type of information reporting may not be considered critical for the researchers as they choose to not explicitly report on the questions, answers, and summaries. This is a challenge for other researchers that are seeking to review, recreate, or rediscover the authors' findings.

In an extremely coarse analysis of this reporting, the level of detail of the process is evaluated for each paper at roughly the paragraph level. Only eight of the papers had a discussion on the interview process between five and eleven paragraphs. An additional seven papers had only two to four paragraphs detailing and explaining the interview process. All other papers' discussion on the interviews were limited to, at most, one paragraph. This implies that there is little recognized need to detail and explain the research methods and tools employed in this type of investigation.

Finally, while *Research in Engineering Design* is an internationally recognized journal, the preponderance of the authors that are undertaking and reporting in this journal their research based on interviewing come from European schools with twenty five instances of author countries. North America, including both these United States of America and Canada, were found in eight instances. Finally, three instances were found from other countries, including Israel (Tribelsky and Sacks 2010), Australia (Wasiak *et al.* 2010), and the United Arab Emirates (El-Tayeh *et al.* 2008). While not statistically significant, this does suggest that the frequency and use of interviewing as a research tool perhaps has some bias in different communities of researchers. This is important for researchers to recognize as they seek to share their findings with the broader research community in that they are tasked with communicating with researchers who might be familiar with interviewing as a research tool. An approach to addressing overcoming this hurdle would be to report more extensively on the details of the research process used.

Overall, with the challenge of differences in acceptance and use of interviewing as a strategy, the limited level of discussion of interviewing details, and the lack of information typically shared through the papers, we believe that it is important to provide an operational approach to design one's own interviewing method instrument and clear recommendations on what information elements are important to report when using this research method.

3 Defining the Context in which the interviews take place

While the purpose and role that interviewing as a research tool is critically important, we reserve this justification to the researchers. We have sought to provide some explanation and justification for how interviewing might be chosen, but here we focus on defining the operational aspects of interviewing. Specifically, we first begin with defining the context of the interview which is a relationship between the interviewer, the interviewee, and the organization being studied.

Interviews are a personal and intense interaction and the experience of interviewing is different for every person who carries out interviews. Therefore everybody must find their own way of conducting interviews that work for them as a person, but also for the role with which they approach the interview. These roles are discussed in Section 3.2.1. The success of interviews depends on getting people to open up to the interviewer and giving open responses to questions.

On one level an interview is first and foremost a dialog between two people; the interviewer seeking an understanding and the interviewee providing information from which to construct this understanding (Walton and Krabbe 1995). This dialog occurs within the social constructs, for example manners such as politeness, that govern the behaviors of the two participants (Pask 1976). As such, an interview needs to work on the level of the conversation for all parties involved. This means that all parties should feel comfortable in an interview and that all parties feel like they are gaining value through the conversation or at the least not feel that they are wasting their time during the exchange. Both parties have to prepare for an interview and invest time into carrying out the interview. The value of the interview must be offset against the cost of the interview. For interviewees and their organization much of the

value lies in the feedback during or shortly after the interview. Thus, an objective in designing the interview should be to be as efficient in information collection as possible. This will be discussed in Section 4.2.

The value-added of the interview should not be confused with that of the research at large. For the researcher, the value of the interview might well be that of contributed to achieving the goal of the research, but an interview can provide insights that go beyond the immediate goal of the research. Researchers can revisit interviews over many years exploring patterns not previously sought or considered. In this way, the interviews can provide a rich source of data for many different research objectives. For example, researchers interpreted the communication between knitwear designers and technicians (Eckert *et al.* 2001) again in terms of ambiguity of representation (Stacey and Eckert 2003). This corpus of interviews were then used to explore the importance of formality in communication that was not previously studied nor the objective of the initial set of interviews (Eckert *et al.* 2013).

For the interviewees, the value-added rarely lies in the results of the research, even though these might motivate them initially to participate. Thus, the interview must either provide value immediate or shortly afterwards. The value can lie simply in the fact that the interviewer is taking time to reflect in the interview and has a listener who is keen to hear about it. This should not be under estimated, since professionals rarely take time to reflect over their own practice and usefully find also that colleagues rarely have time to listen. The interviewer therefore becomes a sounding board. The interviewer can direct this self-reflection through question and make the interviewee think about issues that they would not think about themselves, or draw new connections. The interviewer also can provide feedback during the interview either through their verbal comments or body language. One of things that the interviewees are usually lacking is insight into the problems that other practitioners are facing. Therefore, it is difficult to differentiate between problems that are inherent in the defined processes, designed artifacts, or tools used and those that arise from their own individual or team behavior. The researcher also can provide immediate feedback in the interview, but needs to proceed with caution to avoid preempting and biasing the analysis of the data and affected other interviewees indirectly. For example in the communication between knitwear

designers and knitwear technicians, the designers and technicians blamed either themselves or the other group, according to personality, for difficulties in communicating. They found it helpful to have the interviewer observe that this was a general problem arising from the representations they are using and not unique to their situation (Stacey and Eckert 2003).

For the organization, the long term benefits might well be the results of the research, but companies tend to agree to studies often for more short term motivation. They might be interested in feedback on their processes where the researcher can highlight what works poorly and works well. In particular, academic research seems to be a welcome way to independently and objectively corroborate what management consultants might recommend. Organizations might also like to initiate discussion amongst their employees on the studied topic as a way to initiate reflection within the organization. This becomes obvious when people approach interviewers and ask to be interviewed as well, either because they feel they have something to contribute to the subject matter or because they like somebody to listen to them. The fresh, unbiased perspective of the researcher can be a good way of uncovering issues that would otherwise be taken for granted by asking questions that an insider might no longer ask. For example, in a study with a sports car company, all subjects were asked whether they had company sports cars (Eckert and Clarkson 2002). The answer to this was invariably “this is a silly question” but with two following strands of answers being “of course how would you turn down a sports car” and “what would I want with such an impractical car”. These insights suggest an underlying perception of sports cars engineers. These insights can be shared with the company to help inform their understanding of perceptions within their organization. As we will argue in section 6.4, it is generally good practice to provide a feedback summary or presentation at the end of the study to the organization to discuss the findings with the subjects. This can provide both a validation for the researcher and a summary for the organization.

It should not be underestimated that both individuals and organization can be happy to be interviewed, just to help researchers or their institutions. They remember from their own student days that students occasionally need help and therefore are happy to provide it.

However this usually does not go beyond a single interview unless they find it genuinely interesting themselves.

While each party, interviewer, interviewee, and organization all seek value, in some form, the selection of the organization, the interviewees, and the topic of study is not in strict sequential order. Figure 1 illustrates how different elements of the interview system can be related through two sequences of paths that define the context. For instance, in the red path on the left, the interviewer might have access to a company and a specific product or process might be chosen by the company for its own needs based on the interviewer's access or expertise. This leads to a pool of interviewees with relevant knowledge. Interviews with these people can lead to identification of topics that should be studied further by identifying issues and challenges. Alternatively, the green path might start with the interviewer identifying the topic of investigation, and then selecting a product or process that might serve to illuminate issues within this topic, which leads to selecting companies that could be studied, and then to the persons of interest for the interviews. These are two illustrative paths that link the researcher to the interviewees, topic of study, and organizations. Factors, such as the time available to the researcher, based on a need to graduate or a limited scope internship, might further influence the selection of the different case context.

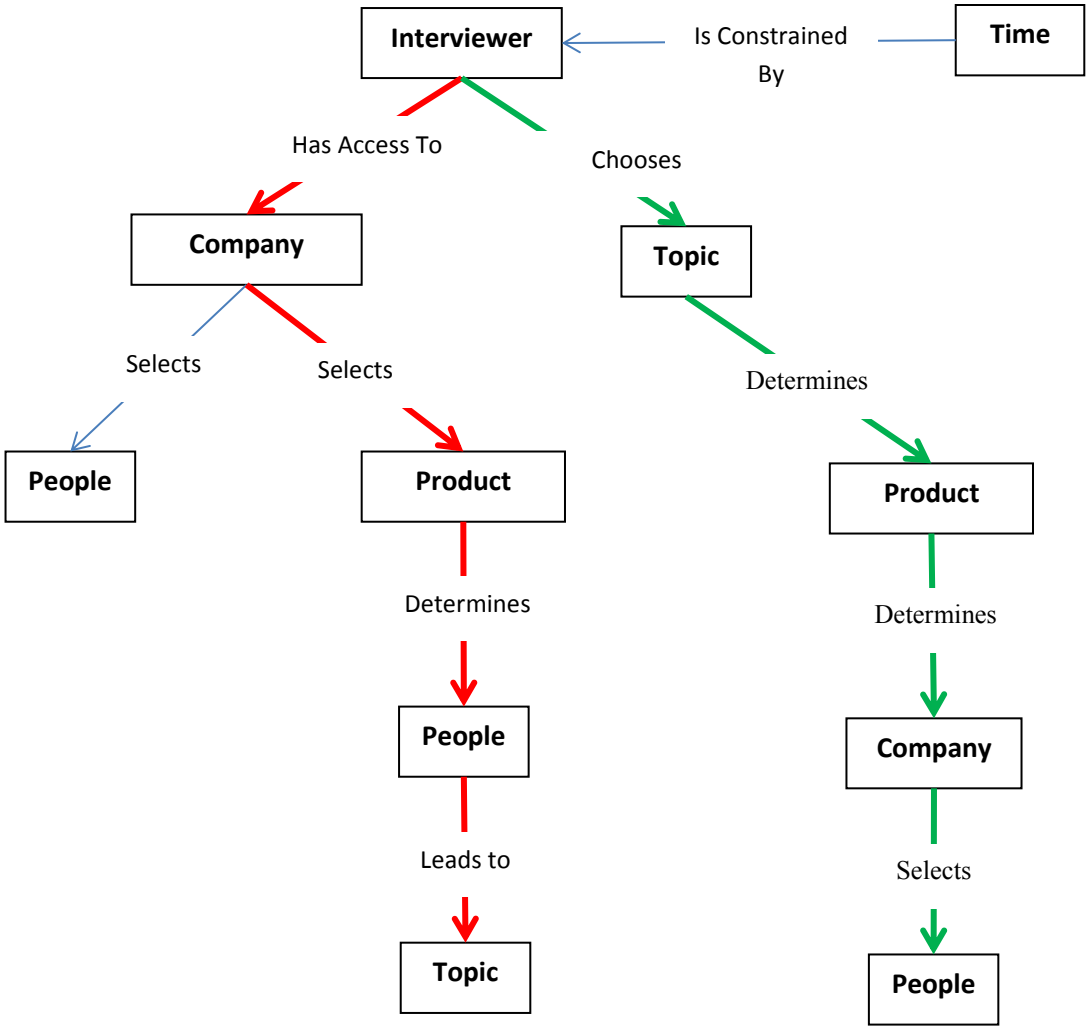

Figure 1: Possible Paths to Define the Interview Context

3.1 The role of interviews in a research study

As section 2 has illustrated, interviews can play different roles in research and are therefore configured in different ways. First, researchers might be interested in studying perspectives of similar individuals, such as innovation managers (Bertoluci *et al.* 2013) across multiple different organizations. This horizontal study uses replication as a form of triangulation. This would require the researchers to coordinate between many different organizations and concerns of confidentiality must be addressed before initiation of the research. Alternatively, researchers might want to construct a case study based on a single organization but with several interviews of personnel at different levels or with different functionality. This vertical study seeks to understand a phenomenon from multiple

perspectives. The question protocols therefore might need to be adapted to the specific knowledge of the each interviewee, while keeping other questions constant across all interviews to ensure objectivity. The research must define the study of investigation and design the interviews accordingly.

Beyond differentiating between the types of research, three types of interviews are suggested as a coarse classification. These have different influences on how the cases and the interview subjects are selected, given the goals of the overall research program:

- *Question seeking interviews* are usually initiated with an interest in a specific topical or problem area. These interviews can be broad and explorative with the goal of identifying research questions or hypotheses and reporting unexpected insights (Eisenhardt 1989). This also allows the researcher to identify the "hurts" in an organization; the places where they have a particular problem or challenge. Addressing these hurts means that companies are quite motivated to work with researchers. This type of interview study typically involves interviewing a range of people in an organization who have interesting perspectives or particular problems.
- *Question answering interviews* are aimed at finding answers to particular pre-defined questions. These are targeted at people who have suitable expertise and insights either within one organization or across a number of different organizations. This type of interview can be used in both horizontal and vertical research, similar to how case research can be structured as single case analysis or cross-case analysis (Yin 2003).
- V*erification interviews* can be used to validate or, more precisely, falsify a hypothesis or model. These interviews can go back to the organizations in which question seeking or question answering interviews were conducted or can approach a different company. Verification interviews can occur at all stages of research to assess the scope and applicability of the current state of the research. For example after question seeking interviews in an organization, it might be appropriate to approach another organization to see whether the same issues occur there. Similarly at the end of a study it can be helpful to return to the same organization or approach different ones to explore how the findings might be generalized. In theory, it would be good to do interviews until one learns nothing

new reaching a knowledge asymptote; in practice a few additional interviews can already increase the confidence in the finds of a vertical study (Baker and Edwards 2012, Rowley 2012).

3.2 The case

Interviewing requires time and commitment from the both the interviewer and the interviewee, therefore it is important to gain and maintain access to a good case to study. What constitutes a good case study depends on the topic. For some topics, such as component change management driven by aircraft engine aerodynamics (Eckert *et al.* 2004) only a small number of people would be suitable interviewees and it is therefore critical to gain access to those people. For less specialized topics, for examples aspects of process management in engineering (Eckert *et al.* 2001) or the role that prototyping might play in conceptual design (Stowe *et al.* 2010), many companies could provide suitable case studies.

While the suitability of a case is defined by the research and the interviewer, we suggest four different approaches that have been successfully applied to gain access to the interviewees:

- *Contacts from a previous case*: If the company found value from the previous interaction, then they are more likely to welcome additional interviews. For example, the studies on engineering change (Jarratt *et al.* 2006), on design teams (Flanagan *et al.* 2007), on system architecture (Wyatt *et al.* 2009), and on the role of testing (Tahera *et al.* n.d.) were conducted in the same organization were all conducted with the same organizations. Moreover, this is beneficial to the researcher as the research team also is familiar with the organizational context, including its processes and, possibly even, its idiosyncrasies. This previous relationship can be a strong advantage in conducting the interviews.
- *Previous work experience in the company*: The interviewer or others from the research team have worked within the organization, thereby gaining access to the organization. Examples of this type of access include the interviews conducted to form the understanding of line-sustaining engineering change sources (Shankar *et al.* 2012), or in collaboration on other projects, such as the lunar non-pneumatic design project (Stowe *et al.* 2008) that

opened the door for a prototyping related set of interviews (Stowe *et al.* 2010). This relationship also provides the interviewer with direct knowledge of who might be the more beneficial and receptive interviewees.

- *Personal and social connections and networks*. This approach might be useful to gain initial access to the organization, but it needs to be followed quickly with a clear value proposition for the company. As an example, a researcher gained access to a local company through fellow student contacts who had previously interned in the company (Hess and Summers 2013).
- *Cold call.* This approach is one in which companies are contacted without prior relationships based on the intersection of the product or domain and the research topic of interest. This type of contact requires significant preparation and background research to access suitable companies and suitable roles in the organization who could authorize a case study. One must find a senior person to whom they can pitch the study directly. If this person has recognized challenges internally related to the subject of study, they will be interested in discussing the possibility of interviewing to study the problem deeper. Often, if the initial person contacted has not experienced the challenges associated with the problem of study, they can offer someone else in the organization who might be more interested. In the knitwear case study most of the contacts were made through cold calling with a well prepared pitch (Stacey and Eckert 2003). This was successful because there are few academic studies of knitwear and due to the scale of the process one or two interviews can provide a good insight. It is important in all situations to try and access the organization through the manager level in order to ensure positive access to the subjects.

Interview studies can be started or set up from different places in an organization which can have the potential to influence the findings of the study to some extent. Therefore, care should be given to both the consideration of how the interviews were set up and also how this is represented transparently to the reader. One approach with respect to how interviews might be established is when a senior person or line manager assigns people to come to interviews. This might be a quick way to arrange the interviews, but can leave individual interviewees with the feeling that their bosses have sent the researchers to investigate something specific. In this

manner, the interviewees might initially have a sense of mistrust. If the company climate is good and the senior person is trusted by the designated interviewees, this might not be a problem, but in a general atmosphere of suspicion this can make interviews more difficult. *In this case both the support by the company and the modes of feedback by the researcher need to be transparent*. Alternatively, a company expert who is not a direct supervisor might be able to convince individuals to participate in the interview based on goodwill and their selection by this expert to represent the organization. This approach has the potential to have a cascading effect when one expert suggests another to interview who, in turn, suggests another, thus providing a large set of potential interviewees.

For most studies it is important to get timely access of companies. One of the real pitfalls of interviews can be companies who are in principle willing to take part in a study, but delay the interviews repeatedly for small periods of time, such as for holidays, project deadlines, or absences. It is possible to accelerate this by providing the companies with genuine reasons why the study needs to be conducted. For instance, perhaps the researcher is about to complete their work, the researcher will leave the country, or the researcher will go on maternity leave. *People often find an hour when they need to be interviewed within the next few days, but put of an hour interview for months if they feel they have a choice.*

Therefore, it is important to be pragmatic about finding interview case studies and pursue several avenues as contingencies. If a second previously unplanned study occurs, it can provide a valuable means of validating the findings.

A final recommendation on access relates to the scheduling and organizing of the interviews. It is useful to find an internal personal who can help with organizing the interviews and who has access to the potential interviewees' schedules. Companies often only provide names leaving the researchers with complex negotiations with the individuals about how and when to interview those whom they have not yet met. Typically the study starts much smoother when an internal person books slots into a people's schedules. If this person is well respected interviewees will participate.

3.2.1 Interviewees

Within a company, the researcher might have limited choice about whom they can interview. Both the level of expertise and experience of the interviewees might be determined by the people who help in planning the interviews. The often direct the interviewer towards senior people with experience of a broad range of issues which can have the downside that they might provide a top down or official view in terms of how their team ought to act rather than does act in practice. For this reason, it is useful to try to gain multiple perspectives within a company from different ranges of hierarchy, ideally from more than one person in a particular role or level of hierarchy to reduce the effect of personality. Similarly, it is useful to people in competitor companies to gauge the influence of the market, if this does not violate confidentiality agreements.

In terms of interviewees, it is important to gain access to not only experts but also individuals who can trust, and thereby share with, the researcher. It might well be more useful to gain access to a junior person, who operates within the team and has an interest in the topic rather than waiting for a senior person's availability for the interview. The junior individual might be willing to share challenges that they experience which might be considered "solved" by the senior personnel. Moreover, the trust of the interviewee is also highly dependent on the interviewer. This trust might be influenced by personality, age, and domain of specialization by the interviewer. As an example, in a case study on undergraduate leadership in design teams, the interviewer was a graduate student coach rather than a faculty member to allow the students to respond more openly during the interviews (Palmer and Summers 2011). Ultimately, the important goal is to foster an atmosphere in which ideas and opinions can be exchanged freely. Therefore people of the same age group are sometimes more likely to establish an instant rapport.

3.2.2 Interviewer

As mentioned previously, interviews are conversations between people and therefore are personal. However, depending on personality, experience, and demeanor the researcher might assume different roles in the interview. As many interviews are conducted in teams, it is worth coordinating this through careful planning and forethought with respect to the message

that the interviewer would like to communicate with respect to the role that they are assuming. This message can be conveyed through the materials brought to the interview, the attire, and even the body language of the interviewer.

Four types of roles that might be seen in the interview are the counselor, the reporter, the detective, and the casual visitor. This is not an exhaustive list, but we present it to help focus the attention of the interviewer on this critical aspect.

- A *counselor* listens to people. While listening, the counselor allows the interviewee to discuss the topic of interest in order to get the interviewer to expose the underlying assumptions. The counselor has heard these issues before and can provide people with advice that is trusted. The counselor should be mutually acknowledged as having a level of expertise that informs the advice.
- A *reporter* tries to find and report facts objectively and without editorializing. The role of the reporter is to "discover" the story. The reporter might start only with an impression that there is something interesting to investigate and pursues the story until it has crystallized. A challenge with the reporter role is that the interviewees might not appreciate the "fishing" expedition with a wide ranging investigation unless, again, they can find value in the effort.
- A *detective*, in contrast, has a specific "case" to solve which requires the detective to uncover the truth and the reasons underlying a phenomenon. This requires a more specific line of inquiry. Moreover, as with good detective work, corroborating evidence is sought to uncover the truths that others might be hiding, even unintentionally.
- Finally, a *casual visitor* might simply initiate a conversation without giving the impression of necessarily looking for anything specific or passing judgment on a situation. This tone is generally amicable and friendly, creating the mood for a pleasant conversation.

An interviewer can set the tone of the interview by the role that they adopt. Likewise, the status of the interviewer also influences this tone (Eckert 2004). People behave differently towards a student interviewer than they might towards a senior, credentialed researcher. This level of influence will vary according to the culture of the interviewee and organization.

Interviewees are affected by whether they see the interviewers as an expert who knows more about the topic, as an equal with whom they can share experiences, or a junior person whom they educate about the topic. Many interviewees like to see themselves in the role of the expert who wants to share this expertise with the interviewer, even going as far as rephrasing the questions that they are asked into what they think they ought to be asked. To support this tendency, it is possible for the interviewer to place themselves deliberately in the role of an apprentice who can share their challenges or naivety as a prompt for the interviewee to provide explanations and details. This expert-apprentice dynamic can also allow the interviewee the opportunity to admit problems not previously acknowledged in order to empathize with the apprentice-interviewer. For instance, in the knitwear studies, the interviewer, as a student, was told what they thought the researcher needed to know, denying that there were technical challenges in realizing designs. However, when the apprentice-interviewer explained that she was, herself, having specific problems, the interviewees admitted that they also had experienced these and could both empathize and offer examples of how they resolved them. In this manner, the interviewer was able to shift the relationship, forming a reason for the interviewee to trust the interviewer and thereby honestly sharing the examples for which the interviewer initially searched.

One final consideration relates to the potential for the interviewer to be intimidating during the interview. This intimidation might not be apparent to the interviewer. One example might be with novice interviewers who might try to assert themselves during the interview by sounding overly clever. This “over compensation”, can come across as arrogant and confrontational to the interviewee. Other sources of potential intimidation might include professors (interviewees might associate a professor with previous interactions with authoritarian professors during the interviewee’s collegiate days), prestige of the interviewer’s university (extremely well known and reputed organizations can carry a level of gravitas that might cause the interviewee to temper their opinions to avoid embarrassing their own organization), and age discrepancies between the interviewer and interviewee (a senior engineer might feel ill at ease in justifying his or her decision making to a young interviewer just as a novice engineer might worry about her or his position when interviewed by a researcher

with significant experience). These potential sources of intimidation are offered to highlight the importance of considering all aspects of the interview. Again, if the interviews are considered to be a form of conversation, the researcher can adjust the interview accordingly.

3.2.3 Configuration of the Interview

Often, interviews are considered one-to-one exchanges. However, in some research interviews, the configuration can include multiple interviewers (Clarkson and Eckert 2004, Almefelt *et al.* 2006) or multiple interviewees (Almefelt *et al.* 2006, López-Mesa and Bylund 2011, Ahmad *et al.* 2012). This changes the dynamics of interviews and requires preparation. Interviews with several interviewers can be interesting conversation, but can also be quite unproductive if the different interviewers are pushing the questioning in different directions. Interviewing together requires the interviewers to be aware of each other's line of reasoning so that they can play off of each other, as in an elegant jazz session. This might include recognizing an interesting thought expressed by the interviewee that needs deeper exploration or it might mean assuming the primary role when the other interviewer appears to be losing focus. Team interviews run the risk of interview partners derailing each other's carefully trail of questioning by asking unrelated questions and taking an interview away from a certain line of inquiry. One of the interviewers might also assume control over the interview either because they dominate conversation or because the other interviewer is introverted. Both can happen with students and advisors, when students are either assertive or shy.

Organizations might offer interview sessions with groups of individuals allowing the researcher to gain multiple point of views simultaneously. While this can be an efficient way of gathering opinions and to observe the discussions between participants, it can also introduce challenges. For instance, the strength of personality of one person may dominate the discussion, precluding others from fully engaging or expressing their opinions. Moreover, the social dynamics and pressures within the group might limit the responses, even when prompted by the interviewer. Another challenge in group interviews is the delay between responses of the participants might lead to a feeling of boredom for the interviewees, which reduces the engagement levels. While interviews with groups of people can be useful, care

should be given in structuring the interviews, specifically to address the concerns above, such as by conducting the interviews in a neutral environment.

3.3 Planning the interviews

Setting up interviews requires considerable practical and intellectual planning. The interviews need to be seen in the context of the entire research endeavor, so that a series of interviews does not develop a life of its own. For example, conducting twenty interviews to validate the findings of a student research project six months before the anticipated completion might be more effort than the value of information gained.

Planning interviews can start at different points depending on the nature of the research questions and the access to experts in companies. From the questions, it is possible to understand the type of experts and the number of participants that are required. This determination should be made by the researcher with input from the cooperating organizations. It is rarely possible to get exactly the people one would like to talk to, so some flexibility and contingencies in the planning is required. Therefore, it is worth thinking about additional potential interviewees recognizing that the interviewees may suggest others to be interviewed. Interviews can take place in a single company or a range of companies, further complicating the planning process. The duration and scope of the interviews generally depend on the research question, but it is worthwhile to realize that that neither interviewers nor interviewees can concentrate for longer than a couple of hours at a time. Considering this further, well-meaning company organizers might try to schedule a full day of back-to-back interviews to maximize the efficiency of the research teams' visit to the company. While this can save on travel time, it might also mean that (1) interviews may be terminated artificially early or (2) the interviewers can get tired, and therefore inattentive to the nuances that are key to real-time adjustment for questioning and clarification. In the authors' experiences, scheduling at most three interviews in a day and leaving about an hour between them seems to be the most that can be productively done. Further, leaving time to have lunch or coffee with interviewees can also be a useful way to gain additional information in a more informal environment while further establishing a sense of trust between the parties.

Interviews can be conducted as a block with all the interviews being done in a short space of time or the interviews could be distributed over extended period of time. Spreading the interviews out over a longer period means that there is time to analyze and reflect, so that more in depth questions can be asked or results from the interviews can be validated through the subsequent interviews. Moreover, if the researcher needs to revisit the same interviewee to gain more information for either deeper clarification of validation of the responses, then it is good to consider spreading these interviews over a longer period of time. As an example in studying the role of virtual and physical testing, four interviews were done with the same company experts that were interspersed with interviews with other experts across a one year interval (Tahera *et al.* n.d.). Ultimately, the time pressure constraints on the researcher may preclude spreading the interviews across a long period of time. Other complications might arise within the organization as duties and responsible parties may change. Therefore, care should be paid to the planning at the onset.

On the other hand, block of interviews can have the advantage that the immediate previous interviews are still fresh in the mind of the interviewers and at the same time are likely to be quite similar to each other as the understanding of the interviewer has not developed significantly between the scheduled interviews. A hybrid of the two, which can work well is doing the interviews in two groups, date gathering interviews, which are then analyzed and validation interviews where the results of the analysis or tools or methods resulting from it, as enhanced or validated.

4 Designing the Interview

Gaining access is the first part of preparing the interviews. Before starting a series of interviews, the interviewer should do background research about the company and the product to avoid wasting time on these background questions. Questions need to be prepared prior to an interview series and revised before individual interviews, even if the particular questions are never asked. This section presents some discussion on the design of the interviews.

4.1 Preparing for interviewing

It is first recommended that the researcher develop a broad understanding of the organization and individuals where possible. In this manner, the interviewer will be equipped to adapt as the interviewee makes use of company jargon, acronyms, or even discussion on custom technologies and tools. The technology background is the most straightforward for the researcher to gather relating to the company's product offerings. It is useful to understand the basic solution principles of the product and the names of the key components that are in the product. This provides some general context that allows the researcher to quickly process the interviewee responses and generate clarification and verification questions. For instance, understanding that the Jet Propulsion Laboratory's mobility group has designed many different systems for different customers and environments, the researcher might be able to ask about prototyping challenges in traction systems at different scales rather than only for the large scale system currently under development (Wilcox *et al.* 2007, Stowe 2008, Stowe *et al.* 2010). The complexity of the product and fundamental technology included provide useful clues for questions or pertinent issues. For example most complex engineering products require sophisticated control necessitating that the mechanical and electrical engineers interact with computer scientists. The communication exchanges across these expertise and often organizational boundaries can be followed to understand how well processes are working in general (Clarkson *et al.* 2004).

Learning about an organization can be more difficult than understanding the product. At the least, it is valuable to learn about the company's organization, structure, history, and corporate philosophy from websites and annual reporting documents. Again, this context can help inform the interviewee. For example recent mergers can be interesting conversational starting points as the interviewer provides an opening for the interviewee to comment on recent developments, the interviewer also provides evidence that they are interested in the organization. Specific company processes are rarely presented in the public domain, but they might be discussed indirectly in research publications. For some products, such as jet engines, it usually generally clear which cases study company is being discussed. If the interviewees come from a range of disciplines it is also useful to learn about the specific discipline and its main concerns. Essentially, it is valuable for the interviewer to "learn the language" of the

interviewee so that they can converse from a common frame of reference. For those interviewers that already have experience with the discipline, organization, and even the interviewee subjects, this process of "learning the language" is likely robust.

4.2 Preparing questions

Entering interviews without adequate preparation can be a real missed opportunity, because even though it may be possible to return to ask question that one has missed, it is difficult to recapture the flow of the argumentation dialog, and more importantly the trust between interviewee and interviewer might be damaged. The specific question types will be discussed in Section 4.3. The ordering of the questions will be discussed in the section on interview strategy (Section 4.4). First, though, it is important to discuss how the questions might be generated and reviewed.

A list of topics might be developed that span the area of investigation. This can be done with mind mapping or outlining strategies with the goal of relating the questions to the research objectives and developing an organization of the topics. The set questions will need to be reviewed and revised in the cause of the interview preparations. As we have argued in section 3 interviews vary both in specificity and formality, and the preparation varies accordingly as the two contrasting examples illustrate.

The prototyping study (Stowe 2008) aimed to find evidence for patterns of use of prototypes. Here the researchers developed specific and focused questions going through five iterations to refine the questions to (1) ensure that the questions mapped to the research objectives, (2) that the questions were focused on the subject of study, and (3) that the questions did not repeat beyond necessary triangulation. Table 5 illustrates a table that is used to verify that questions and propositions are sought at least three times in an interview plan to support within-interview triangulation for the prototyping study. This approach to systematically comparing the questions is useful to validate and select the set.

Table 5: Interview Triangulation Checklist

Question	Interview Occurences	Propositions	Interview Occurences
Role of Prototyping?	4	*Effective Prototype Dependent on Factors*	6
Role Effected by Design?	3	*Factors can be Determined*	3
Effect of Collaboration?	4		
Influence on Effectiveness?	3		
3 occurences needed for triangulation			

The researcher conducted a pilot interview with his advisor, who played the role of interviewee to help train the student in conducting the interviews. This practice interview provided an opportunity to discuss the researcher's demeanor and the questions that were asked. This has proved to be effective as both a teaching and a question review tool (Stowe 2008, Teegavarapu 2009, Hess 2012, Shankar 2012).

The interviews on engineering changes reported in (Eckert *et al.* 2004) where aimed to identify, rather than validate, patterns of behavior. To prepare the interviews, a large number of questions were generated with some focused at change, but many were generally about how the engineered system and the organization. The questions were grouped under topics and some questions were combined. The questions were than reviewed by two colleagues, who commented and added to the questions. This question databank generation is similar to the iterations of the semi-structure interviews described above. The primary difference is intent of the refinement. The verification type of interview required focused questions, while the exploratory interviews required breadth of coverage. It is useful to "pilot" interviews with lab mates or fellow researchers to gage the interview duration, the flow of the questions with respect to aligning as a conversation, and which questions could be supplemented with requests for examples. However, as interviews also are tailored to the interviewees and their responses, a pilot interview will likely be different from the real thing.

During the change study interviews each topic was explored with each interviewee, but depending on the expertise of the interviewee some interviews went into more details on particular topics. The interviews were conversations where the questions were frequently rephrased to suit the flow of the conversations, for example in some interviews a question might be asked in the context of discussing an example or a different topic. Similarly, the

questions in the structured interviews on prototyping were reworded and adjusted during the interviews as necessary to ensure that the coverage was complete.

In designing questions, it is useful to think about the specific knowledge of the people who are being interviewed and the perspective each can provide. Not all questions are suitable to all interviewees and, therefore, the questions need to be distributed to the appropriate interviewees. While it is useful to gain multiple perspectives on the same topic and to assess the understanding of multiple people about the same issues, there is not much value in either asking question to which one has already obtained an answer, such as "what the product development process is", or to ask people something that they are unlikely to know, for example to ask a purchasing person on technical details. Conversely interviews should take advantage of the specific knowledge of the interviewees, for example exploring supplier selection aspects with the purchasing person.

Systematic design of the questions and relating the individuals with the research objectives and the interview questions is extremely important for internal validation of the research instrument – the interview process.

4.3 Questions

While an interview is a conversation, it is also a composition of questions that will lead to the answers to develop the understanding of the topic being studied. Different classes of questions anticipate different types of answers, similar to how dialog can be classified (Walton and Krabbe 1995). Pragmatically, seven types of questions are suggested here:

- *Ice breaker* questions get the interviewee going and stop them from being self-conscious. These can be questions about their own background and role or asking them about how they liked the product or many even issues outside of design.
- *Fact finding* questions aim to understand aspects of design processes or products with the assumption that there is a clear answer to these questions. These questions can have binary, numeric, or verbal answers. Often the answers to those questions can be obtained through other means then an interview, for example "what is the average fuel consumption of your engine?" does not require an interview, but could be answered through document analysis or direct surveys. More importantly, the interviewees might

not know the exact answers to fact based questions and would, themselves, be forced to look up the correct answers. Moreover, once a satisfactory answer to such a question is obtained, the question does not need to be asked again.

- *Level of interviewee understanding* questions might be used to assess the range of expertise of the subject. These questions are asked to several people to see the range of answers one would engage. This can be very revealing, but also frustrating if one has no objective way of electing a correct answer to a factual question. Essentially, these questions can be used to form a baseline understanding.
- *Confirmation questions* where the researcher knows the answer or think they know the answer and require confirmation from an interviewer. These can aim at facts, but also the interviewers own emerging understanding of the design situation or its problems.
- *Close precious questions* are related to *fact finding questions*, which focus on particular issues, facts, or opinions. These are well-framed and introduced to gain as precise an answer as possible for example in terms of setting the context for the question. This type of question is related to clarification around specific examples. These questions can be directional, forcing the conversation to a specific topic, but they are not leading questions.
- *Requests for explanation* are those through which the interviewees are asked to explain how certain aspects of their processes work.
- *Catalyst questions* seek to get the interviewee talking around a topic without leading them. Catalyst questions are useful to discover issues that the interviewer had not considered *a priori*. These can be useful to the conversation as a means to get the interviewees to discuss issues on which they would not otherwise comment. For example in the knitting studies the interviewer asked designers to describe their design processes gathering many explanation of the process. However, by asking about how the designers related to the buyers from their main customers revealed much about the interfaces of their processes and the problems in the processes as these could put the buyer relationships in jeopardy or increase stress prior to meeting.

- *Opinion questions* are those in which the interviewee is asked about their opinions on a particular situation or issue. While one can often gather this from other answers, clear statements can provide clarity as potentially good quotes that can be used in support of the findings.

While these question types are not formally defined, they can serve as a guide in checking to see that the questions defined for the interview are not all of the same type. Variety of question types can provide the interviewer with a more natural cadence during the interview to keep it from sounding like an interrogation.

4.3.1 The role of examples

In the *close precious questions*, examples are important as they enable the interviewee to consider issues through specific lens thereby helping to expose the contextual background that affects the perceptions of the interviewee. Moreover, the way interviewers think can be abstract where an example is an obvious way to relate this thinking to the world of the interviewee. In this manner, interviews can provide access, or at least a route to access, the deeper meaning through these examples.

Examples are often volunteered by the interviewees. When not volunteered, the interviewer can request them explicitly. It might be valuable to use a single example throughout the interview to create a common thread for understanding. Examples can be introduced by the interviewer for comment. These might come from previous interviews or by returning to earlier portions of the conversation.

Prompting interviewees to stick with one example or asking them how the situation would play out for another example can be useful, provided that both the interviewer and the interviewee are conscious that this is speculation by the interviewee and that the answer has a different status. Sometimes no real examples are available and researchers need to construct examples. This can play a role in explaining concepts to the interviewees and to elicit real examples from them. For example change propagation can be easily illustrated by talking about increasing the weight hanging from a beam. The interviewer should understand the expertise scope and limitations of the interviewee such that the examples are appropriate. Asking an engineer to predict whether reorganizing the corporate decision making structure

would have a positive impact on changes driven by marketing would be overreaching their expertise. Examples from another case study can also be a useful way to elicit both opinions and differences in behavior. This can be a good way to elicit opinions that would not be expressed so directly as a response to a direct question. For example, the author sometimes uses examples from the knitwear industry to elicit comments from engineers, like "in the knitwear industry managers often do not understand the concerns of the designers" to which engineers would reply with a wink "this could of course never happen in their organization", when they would never openly criticize the understanding of their own bosses. *Thus, if fictitious examples are used, then the interviewer should take care that they relevant and domain applicable.*

4.3.2 Seeking comment

While interviews can be used for fact finding, they are also powerful tools to elicit the opinions and viewpoints of the interviewees. In the narrative, each explanation about the issues of study contains a hidden viewpoint or an opinion. Interviewees can also express explicit opinions; in particular when they are aware that their viewpoint is different to that of others or the official organization's view. While these opinions are important, it is worthwhile to save these as concluding questions. Otherwise, the interviewee might focus early on only offering opinions and commentary, which can quickly devolve into a complaint-filled therapy session. Offering scenarios for comments can be a useful way to get designers to talk about processes without pinning them down to their own specific processes. Sometimes it is useful to elicit opinions on specific facts. Again, it is important it recognize the difference between understanding opinions and understanding behavior patterns and to ensure that the inferences and conclusions drawn are tempered accordingly.

4.4 Interview strategy

Designing an interview includes collecting questions and structuring the questions to facilitate as natural as possible a conversation. In practice, it is not always possible to conduct an interview in exactly the way one anticipates, but it is usually possible to follow a general strategy to a certain extend.

4.4.1 Pre-Interview Preparation

The first consideration for an interviewer is what information should be shared with the interviewee before the interview. This information can be used to prepare the interviewee for the discussion, but it can also create a bias in the research if not phrased properly. Explaining to the interviewee the specific research goals and hypotheses can compel the interviewee to try and find evidence to support the hypotheses, thereby biasing the findings. However, if the goal of the preparatory information sharing is to encourage the interviewee to consider possible examples that could be discussed, then the concern of biasing might be mitigated by requesting both examples that might address both hypotheses and counter-hypotheses. In a study on eliciting change initiators, interviewees were presented with a prepopulated relation matrix and asked to bring examples of change issues to the interview (Shankar *et al.* 2012).

4.4.2 General to Specific Questioning

In case study research, and by association interviewing, a common complaint is about the potential for inherent bias in the information and opinion collection. This bias is grounded in the possibility that researchers can direct the interviews, through leading examples and selective questioning, to find only the responses that would support their research hypotheses. One approach to counter this is to seek patterns counter to the hypotheses (Yin 2003). Another approach is to intentionally start with general lines of questioning. This intentional choice in interviewing strategy creates an objectivity barrier against the potential bias of leading the interviewee. Therefore, as examples can lead conversations in specific directions, a "general to specific" strategy is to start with general points before moving to specific information and confirmation of opinions. This can bring out contradictions between general views which tend to be "official" views and the details that the interviewees offer with respect to specific prompts. For example, an interviewee might wish to present a coherent, sequential, rational picture of a development process, which morphs into a highly iterative and dynamic process when the details are discussed. If the interviewees commence with details, they might be more aware that the general principles contradict the examples. However, if the interviewer allows the subject of study to discuss the general process first, then the need to present the "official" view has been satisfied and the specific details can be used to expose the complexities and

potential contradictions without the interviewer feeling conflicted. Thus, as the interview progresses, the interviewee can also reveal more and more of their own opinions and views.

Thus, a good way to start an interview is with a general question, like "what is your role?" or "what do you do in the organization" to get a description of the person's activity, such as with the proposed *ice breaker questions* mentioned above. These might also include asking about how the interviewee reached their current position. The goal is to get the person talking openly and freely, without the interviewee being concerned of contradicting the organization or other interviewees.

The formality with which a question is posed might also bias the answer. For instance, asking "what do you do?" encourages people to talk about actually activities, whereas "what is your process" is likely to elicit comments about the official process that the interviewee ought to follow. These general questions can also allow the interviewer the opportunity to ask for examples that can clarify the responses. These examples can then be used to construct a common thread throughout the interview. Thus, starting with a general question, the interviewer can elicit a fact based example that can be used to ground the subsequent questions.

In describing a design process, interviewees often mention challenges and issues that the interviewer recognizes as common challenges across organizations. In this manner, the interviewer can allow the interviewee to volunteer information. Allowing the interviewee the opportunity to volunteer information about the challenges increases the objectivity of the interview as the progression of the question-answer is not leading. An understanding of problems by the interviewer often lies behind seemingly innocent questions. For example "do you use functional models in your organization?" could lead to an explanation of the method introduction in general or the challenges with functional modeling in particular (Eckert 2013).

The interview, like any conversation, will likely migrate from general to specific and back to general. This flow of the conversation is important and is difficult to anticipate. That is why many of the researchers likely employ semi-structured interviews, rather than strict structured interviews that preclude this naturalistic evolution of the conversation. However, having some structure and planning ensures that the researcher can gather the information sought.

In some cases, directing the flow of information is all that the interviewer can do as the interviewee digresses into long explanations that are tangentially related to the asked question. Sometimes these tangents can be interesting in their own right and might be worth waiting out before bringing the conversation gently back to a planned topic. If these conversations are time limited, then possible tangents need to be managed carefully. Often the people who want to be particularly helpful are challenging to interview with a given set of questions, as they try to anticipate the line of questioning before it develops. Again, the challenge for the interviewer is to balance the natural flow of the conversation that encourages honesty and openness of discussion with the predefined goal of seeking information and understanding centered on a specific goal.

4.4.3 Concluding the Interviews

In concluding the interview, the interviewer might use the opportunity to seek general and personal opinions. This might include allowing the interviewees to speculate on both the reasons for the challenges and the possible solutions for them. This could reveal reflected positions, but the interviewer must take care to differentiate between flights of fantasy and honest intuition. Moreover, at the conclusion of the interview, the researcher might choose to discuss their emerging understanding of the issues encountered. This is after the data collection and could not contaminate the objective information gathering. However, care should be taken if the interviewee might discuss these developing understandings with colleagues who will be interviewed in the future.

5 Executing the Interview

This section concentrates on the practical issues of confidentiality and recording during the interviews.

5.1 Confidentiality

Two aspects of confidentiality are important when interviewing. The first is the confidentiality that the interviewer promises to ensure in order to secure the appropriate institutional review board approval from their institution. These institutional review boards are tasked with oversight of human subject experimentation, including interviewing, to ensure that

subjects are not placed in danger or undue duress. In the US, researchers are required to complete basic training and certification. *Before any interview is conducted, the researcher then secures the permission from the review board, certifying that they will hold interviewee and organization details confidential according to the established best practice of human subject research*.

The second form of confidentiality is held between the interviewer and the interviewee and organization. This is often formalized with a signed confidentiality agreement or a non-disclosure agreement that asserts that the interviewer will not share information of a sensitive or proprietary nature. This is ensured through a typical agreement that the research team will share the findings before publication of the work. These agreements are signed between the researcher's institution and the organization of study or between the interviewer and the organization. Often, when horizontal interview sets are collected, the company specifics are made anonymous, with specific identifying information redacted from the cross-case analysis report. The confidentiality agreements are useful levers for the researcher to further establish a sense of trust with the interviewee.

5.2 Recording interviews

A final challenge with interviewing as a research method is the actual interview data collection. Recognizing that few people are able to take high quality notes while conducting the interview, it is important to record the interviews. Moreover, by recording the interviews, the researcher creates an artifact that can be examined by others in the future. This creates objectivity in the research process as it supports external verifiability of the collected data. These recordings might be converted to transcripts of the interviews, but the original source recordings should be maintained for research qualification purposes. There are various ways of recording interview:

- *Audio Recording* is a simple way to capture an interview. It is necessary to ask for permission of both the interviewee and the organization to record the interview. In order to further establish trust with the interviewee, an option to "go off the record" is important. This allows the interviewee the opportunity to turn off the recording device, but this is

rarely an exercised option. Video recording can also be done to capture the interview, which provides a more robust contextualization of the question responses with gestures and body language. However, the logistics involved with setting up the video at the organization's site typically precludes this option and the value of the additional information is typically not exploited in the interview analysis. Should audio recording be used, it is important to ensure that a strategically placed device is used to capture the conversation in high quality so that later transcriptions can be generated.

- *Note taking* during the interview can be difficult, but it can be useful for tracking the questions that have been asked and answered, for capturing the examples that might be useful for follow-up questions, and for monitoring the conversation in real-time. A second interviewer is useful in capturing the information without interrupting the flow of the conversation. Thus, teams of interviewers might be a useful strategy for researchers to consider. This is typically supplemented with audio recording.
- *Proformas*, or interview worksheets, can be in efficient way to capture information during the interview. These serve two different roles. The first is to facilitate information gathering without intrusion in the questioning, while the second is to provide structure to the line of questioning to ensure that the breadth of the interview is held consistent across interviews. Again, this is typically supplemented with audio recording.
- *Post-hoc notes*, while not done during the interview, are useful to capture the "sense" of an interview while it is fresh in the interviewers mind. This can help provide the contextualization for the interviews while also allowing the researcher to identify portions of the interview that would be of interest to review through the recordings or transcripts. This might include feelings about the understanding that need to be verified with direct quotes.

Regardless of the recording approach, preparation and planning are again central to the research method. This will include ensuring that the equipment has adequate battery life and that a backup device is available. Worksheets for note taking should be prepared. These pragmatics are important to consider so that interviewing opportunities are not lost for technical reasons. Moreover, this preparation will convey to the interviewee that the

researcher considers this an important session. Again, this will help to instill a sense of trust between the interviewee and interviewer.

6 After the Interview

Once the interview is completed, there are a few recommended activities, ranging from transcription of the interviews to analysis of the transcripts and providing feedback to the subjects. It is recommended that a summary of the interview be written within two days of the interview completion. These summaries can provide a comparison/triangulation with the data that is found within the transcripts. If the summaries are written too distant from the time of interviewing, then the veracity of the summary can be questioned.

6.1 Transcriptions

Transcription can be time consuming, with anecdotal experiences of the authors suggesting that for each hour of interview collected about a dozen hours will be spent in transcription. Dictation software that converts audio to text, such as that found in MS Word or DragonSpeaking can be useful for creating a skeleton of the transcription before the research team details the transcripts. Professional transcription agencies or even administrative assistants within the research institution might be able to complete the transcription in shorter time. It is important to justify the cost, be it time or financial, for transcription. One significant advantage of transcription is that it provides an archived record of the interview that can be reviewed in the future. Moreover, it provides a record that other researchers can review, offering further evidence of the researcher's objectivity and the reader's confidence in the findings.

While transcription provides an external, objective capture of the interview, it is important to recognize that many of the nuances of the interview, including body language and facial expressions, cannot be fully captured. Thus, the interviewer impressions through notes should be triangulated with the transcripts. This exposes possible intent behind responses.

6.2 Analysis

In terms of analysis, it is important to define how the interview data will be processed to draw inferences and conclusion before the interview is conducted. This sequencing of planning

is useful to demonstrate objectivity and helps to minimize the potential for bias in this qualitative research method especially where the interview is used for pattern matching. In situations where the interview is used to discover open issues and challenges, the analysis might be developed post interviews. In both situations, providing the reader with a clear discussion on how the analysis is completed will help enhance the research credibility as the reader can reapply the analysis to verify the inferences made. To plan and conduct the analysis of the interviews, there are many approaches, a few of which are introduced here. The approaches vary in their use in addressing the research goals and objectives.

- *Protocol analysis:* Transcripts can be treated as protocols and analyzed on a sentence by sentence level either with an established coding scheme or following a grounded theory approach (Martin and Turner 1986). Protocol analysis is focused on pattern seeking either for anticipated topics or for discovery from the data without prior preconception. One example of an approach to transcript coding for compression purposes is found in (Stowe 2008). In this approach, the responses to the prototyping interviews were translated into a prototyping classification scheme captured in tabular form. One benefit of transcript analysis is that the interviews can be re-coded to explore different in future research. If protocol analysis is used, then the robustness of the protocol should be tested through inter-rater reliability analysis. Providing the protocol to different coders and then testing the similarity between the produced codes demonstrates the repeatability of the protocol, helping to mitigate the potential subjectivity with the qualitative research. It should be recognized that a grounded theory analysis of one's own interview data is difficult as assumption were used in the development of questions. However, if interviews are part of recorded observations, a grounded theory approach can be employed. In practice many data sets including interviews are coded multiple times, as one starts with a set of concepts or questions that have informed the interview and discovers new themes. These new themes can become part of the set of concepts and require a recording of the transcripts. Thus, the rigor of the protocol analysis relates to the research objectives and the type of the interview.

- *Answering interview questions* based on the transcripts is a way of generating a summary of the interviews relatively quickly, which might be sufficient for many purposes. In this method of analysis, the researcher seeks specific responses to research questions, either that have been explicitly asked during the interview or indirectly through unprompted responses.
- *Interrogating a corpus* is a way of looking for specific issues that might or might not have been part of the original set of questions. This approach is slightly different from the *answering questions* in that for this method the researcher is seeking information that was outside of the initially defined set of questions. This is a particularly relevant when interviews are revisited later for different purposes. For example, interviews on system architectures (Wyatt *et al.* 2009) were conducted before the researchers became aware of how little the interviewees had discussed creativity (Eckert *et al.* 2012). The interview transcripts were then interrogated to determine how and when the interviewees talked about creativity, innovation, newness, or other related topics. In this manner, the transcripts were studied for specific key words and themes. This is an efficient method to exploit large data sets of interviews to both gain initial results and to address particular questions.
- *Insights* after interviews from reflection over the interviews or discussion of the interviews. These can expressed as models or hypothesis, which can then be corroborated through interrogating the corpus or discussions in further interviews. This however runs the risk of a confirmation bias, where contrary evidence is discarded or ignored.

6.3 Completing interview series

One challenge with interviewing as a tool in design research deals with determining when a sufficient number of interviews have been done. Typically, an interview plan is developed before the research begins that explicitly states the number of interviews that will be conducted. In this case, it is clear and objective when the interviews are completed. However, even with this plan, if the research goal is to collect information for either theory building or theory testing, the researcher might consider reviewing the plan continuously to determine whether further interviews are needed when weighed against the costs associated

with interviewing. To evaluate the benefit of collecting additional interviews, one can qualitatively check to see if and how much new information and understanding is generated from each interview. If it appears that the research is approaching an asymptote, then the researcher should consider ending the interview collection process. This approach was used in (Shankar 2012, Shankar *et al.* 2012) and is similar to the approach in ethnography (Gold 1997) in which the study is finished when the researcher understands what they see and is no longer surprised with new information. While the decision to terminate may be subjective, it is important to rationalize and support this decision with an explicit discussion in the case reporting.

6.4 Feedback

After each interview session, the researcher should consider providing feedback to the participants. Firstly, it is important to recognize that the interviewee has generously offered their time and expertise in support of the research. A quick note to the interviewee and their supervisor to express appreciation is valuable as it can keep the lines of communication open for possible future follow-on interviews with the subject or through the organization. This "thank you" can be coupled with copies of the transcripts, summaries, or debriefing sessions that can corroborate the interviews. Thus, the second reason to provide feedback is to gather verification about the findings and inferences.

It is important to try to provide feedback quickly for corroboration so that the interviews are still fresh in the interviewee's minds. This can be a challenge with the pace of much academic research being methodically slow. Intermediate feedback and short summaries can be useful if full transcripts are not available in a timely manner. When feedback is provided to the interviewees, it is important to clearly state what and how verification is requested.

Finally, in person discussions and debriefing presentations can be used to verify the inferences drawn from the interviews. These can be used to resolve possible factual misunderstandings or miscommunication between the interviewer and interviewee. For example, if a model of the product development process is generated to describe an organization's approach, a debriefing with the organization about the process can help highlight missing aspects or potential misinterpretations. The organization, including those not

interviewed, can provide feedback on the correctness of the model. This can stimulate heated discussion within the organization, which is not the intent of the research, but could be of positive to the organization. Additional topics and issues might be exposed in these meetings that can help expose issues for future studies.

7 Reflections on Executing the Interviews

The strategy and approach to interviewing to gather information and understanding from individuals and organizations is, in many ways, based on common-sense in how to get responses to questions. This means that the interviewer needs to provide the interviewees with chances to reply to questions without biasing their replies. To avoid biasing in the research, a collection of best practices are offered here.

- First, it is important to remember that the *interview should be a conversation*, not cross examinations or interrogations. The interviewers should gently press the interviewee for information, respecting the boundaries and rules of conversation.
- Further, the *interviewer should avoid appearing to patronize* the interviewee by giving the impression that the interviewer understands the subject matter better than the interviewee.
- The formalism of the interview can suggest to the interviewee a sense of judgment from the interviewer. Thus, it is important to phrase responses to answers neutrally and *foster an environment that is friendly and collegial* during the conversation.
- Interviews often expose contradictions in interviewees' views, descriptions, and shared facts. These contradictions are the intellectual fulcrum in interviewing as a research method. Often, what begins as a seeming contradiction resolves itself as the interviewee further explains their position. Therefore, it is worth letting the description go on rather than prematurely highlighting the supposed contradiction. These apparent contractions might also be found across interviewees. In some case the differences reside in the different descriptions that people choose to use rather than fundamental differences in their underlying meaning. The interviewer should remain vigilant in examining these

potential contradictions. *Again, it is good practice to reserve the discussion of the possible contradictions to the end of the interview as clarification and verification efforts.*

- Sometimes gently teasing the interviewees about these contradictions or other emotive statements can reveal interesting answers while lightening the tone of the conversation. However, as *humor is very culturally sensitive, the interviewer must be sure of the cultural acceptability*.
- *Interviewing generally requires a degree of agility.* No matter how well the interview is planned, the relationship between the questions and their answers can be tenuous; expecting the questions to actually yield all the relevant answers it overly optimistic. Questions need to be rephrased and other questions need to be added to gather the information sought. Often, interesting issues are discovered with these follow-on questions. Employing a set of open ended semi-structured questions and following them slavishly is unlikely to provide good results and can waste a lot of time for the interviewee.
- Strictly following a set of questions is appropriate, if the interview is targeted at behavior pattern matching, where several interviewees are asked the same or similar corroborating questions. *These questions need to be well phrased.*

A common mistake is to underestimate the effort required in preparing for an interview in terms of background research and preparation of the questions. Three common mistakes in questioning include the use of long and complicated introductions, leading questions, and several simultaneous questions.

- Long and complicated introductions to questions can be confusing to the interviewee as it is not clear how they are expected to respond. Even if a well phrased question ends the introduction, the interviewee might find it difficult to respond to the context provided.
- With respect to leading questions such as those starting with “do you agree with…”, it is difficult for the interviewee to offer a counter view as they will likely feel indirect pressure to confirm the interviewers opinions and views. These questions should be reserved for the end of the interview and as a way to corroborate the interviewee’s previously stated points

of view. If used incorrectly, these leading questions can introduce bias that should be studiously avoided.

- Finally, multiple, simultaneously asked questions are confusing and the interviewee might only respond to one of the questions. The interviewer should consciously try to avoid confusing the interviewee, using primarily simply phrased questions.

8 Conclusions and Recommendations to the Community

We argue through this paper that interviews can be useful, rich instruments in design research, provided that the interviews are well planned and reported. As with other approaches to scientific research, interviews need to be conducted as rigorously as possible. There is often a trade-off between the formality of the interview and the richness of the data that can be elicited and the inferences made. However, formality should not be confused with rigor. Interviewers need to prepare for interviews carefully by researching the background of the product and the company as well as by preparing and testing questions prior to the interview. Even though interviews are conversations, preparation is required to ensure that all the issues are addressed and that the interviewer does not inadvertently bias the interview.

The findings from interviews truly can inform design research, but it should be recognized that all interview findings are interpretations of people within given scenarios and contexts. The Delft Protocols Workshop (Cross *et al.* 1996) and the Seventh Design Thinking Research Symposium protocols (Lloyd and McDonnell 2009) illustrate how the same protocol can be interpreted differently by different groups of researcher. The same may apply to interviews, if the interview data is openly shared. As noted, the scenarios and contexts of the interviews can influence the scope of the conclusions and inferences from the interviews. For example, the findings may be tempered based on the type of company, the industry sector, the expertise of the practitioners, the culture of the organization, or other aspects. Thus, this context is critical for readers to develop an appreciation of the work. To offer a credible interpretation of a situation, the researchers need to explain the context of the interviews and the way they are conducted. Table 6 covers the range of issues that we would suggest

researchers discuss when they present the findings of interview studies with examples of this from the design/supply chain study (Almefelt *et al.* 2006) recognized as a good exemplar.

Table 6: Recommended Information to Report on Interviews

Topic	How Addressed in (Almefelt *et al.* 2006)	Justification for Inclusion
Purpose of Research Study	Understanding	The purpose of the research can justify the choice of interviewing as a research tool
Purpose of Interview	Core	The centrality of the interview should be presented so the reader can appreciate the scope of the inferences drawn
Additional Research Methods	Document Analysis	Introduces research instrument triangulation to improve the objectivity of the research method.
Context of Study	Automotive	The industry application can be used by other researchers for cross case analysis and research contextualization.
Organization	Supply/Design Chain	The type of internal organization studied is important to provide context of the research while framing the inferences.
Interviewee	Unknown (24 interviews with 25 people); Engineers, managers, purchasing, and others	Details on who is interviewed are critical for the contextualization of the inferences and to support cross case analysis.
Relationship between Interviewee and Interviewer	Previously worked on project	Exposing pre-existing relationships can address concerns about objectivity and bias.
Interviewer	Pairs	This helps future researchers in designing replication interview studies and to provide potential support for interview triangulation.
Interview	On-site (relaxed atmosphere)	The context in which the interviews are conducted can help inform the inferences drawn from the responses.
Type of Interview	Semi-Structured	The type of interview explains the general structure and flow of the interview for validation and external objectification.
Supplemental Material or Recording	Piloted the interview; Transcript approval	This information is critical for repeating the interview processes in other contexts and scenarios.
Duration of Interview	~60 minutes	This information is needed to support repeating and replication of the interviews.
Questions Reported	Yes	Exposing the questions, or a subset, can add credibility of the researcher from the reader perspective.
Answers Reported	Yes	Exposing the answers and responses, or a subset, can add credibility of the researcher from the reader perspective.
Summary of Interview Provided	Yes, discussed	A short summary of the interview responses before the detailed inferences can provide an objective view of the data collected before interpretation. This adds to the objectivity of the presented research.
Discussion of the interview Process	Approximately nine paragraphs	While not explicitly reported, this provides the reader with an impression of the researchers' rigor in designing and conducting interviews.

This introduces wider issues for the design community at large with respect to how the community handles the results of case studies. In the spirit of scientific research we would

want to replicate our interview studies within new contexts and interviewees. This external verification of the research is only possible if complete details of the interview process are provided for others to follow similar approaches, again recognizing that the interviewer must be flexible and adaptive to new situations. The procedures and details of the interviews can be provided within the research papers without concerns about confidentiality. Moreover, the community should be open to the idea that researchers conducting similar interviews and case studies in new contexts, but drawing similar conclusions, are still intellectual contributions to the design research domain. Beyond descriptions of the interview processes, the collected data itself can be shared, to varying degrees. Ideally, we would like researchers to also share their interview data with other researcher. The degree to which this sharing of the raw data is possible is tempered with concerns for confidentiality with the interviewees and organizations. At the least, sharing the summaries of the interviews and transcript extracts can be useful for others while also increasing the credibility associated with the research. These summaries might be centrally hosted, found within the researchers' websites, embedded within the full student theses, or as appendices in the research papers.

9 References

Achiche, S., Appio, F.P., McAloone, T.C., and Di Minin, A., 2013. Fuzzy decision support for tools selection in the core front end activities of new product development. *Research in engineering design*, 24 (1), 1–18.

Ahmad, N., Wynn, D.C., and Clarkson, P.J., 2012. Change impact on a product and its redesign process: a tool for knowledge capture and reuse. *Research in Engineering Design*, 1–26.

Almefelt, L., Berglund, F., Nilsson, P., and Malmqvist, J., 2006. Requirements management in practice: findings from an empirical study in the automotive industry. *Research in Engineering Design*, 17 (3), 113–134.

Aurisicchio, M., Bracewell, R.H., and Wallace, K.M., 2013. Characterising the information requests of aerospace engineering designers. *Research in Engineering Design*, 24 (1), 43–63.

Baker, S.E. and Edwards, R., 2012. *How many qualitative interviews is enough*.

Bertoluci, G., Yannou, B., Attias, D., and Vallet, E., 2013. A categorization of innovation funnels of companies as a way to better make conscious agility and permeability of innovation processes. *In*: *ICoRD'13*. Springer, 721–734.

Beskow, C. and Ritzén, S., 2000. Performing changes in product development: A framework with keys for industrial application. *Research in Engineering Design*, 12 (3), 172–190.

Cardin, M.-A., Kolfschoten, G.L., Frey, D.D., De Neufville, R., De Weck, O.L., and Geltner, D.M., 2012. Empirical evaluation of procedures to generate flexibility in engineering systems and improve lifecycle performance. *Research in Engineering Design*, 1–19.

Clarkson, J. and Eckert, C., 2004. *Design process improvement: a review of current practice*. Springer.

Clarkson, P.J., Simons, C., and Eckert, C., 2004. Predicting Change Propagation in Complex Design. *Journal of Mechanical Design*, 126 (5), 788.

Creswell, J.W., 2008. *Research design: Qualitative, quantitative, and mixed methods approaches*. SAGE Publications, Incorporated.

Cross, N., Christiaans, H., and Dorst, K., 1996. *Analysing design activity*. Wiley Chichester.

Cross, N. and Cross, A.C., 1998. Expertise in engineering design. *Research in Engineering Design*, 10 (3), 141–149.

Dain, M.-A. Le, Blanco, E., and Summers, J.D., 2013. Assessing Design Research Quality: Investigating Verification and Validation Criteria. *In*: *International Conference on Engineering Design*. Seoul, South Korea: The Design Society.

Demian, P. and Fruchter, R., 2006. An ethnographic study of design knowledge reuse in the architecture, engineering, and construction industry. *Research in Engineering Design*, 16 (4), 184–195.

Donaldson, K.M., 2006. Product design in less industrialized economies: constraints and opportunities in Kenya. *Research in Engineering Design*, 17 (3), 135–155.

Eckert, C., 2004. Status in industrial studies. *In*: E. Subrahmanian, R. Sriram, P. Herder, H. Christiaans, and R. Schneider, eds. *Role of Empirical Studies in Understanding and Supporting Engineering Design*. Delft: Delft University Press, 64–71.

Eckert, C., 2013. That which is not form : the practical challenges in using functional concepts in design. *Artificial Intelligence in Engineering Design Analysis and Manufacturing*, 27 (3), to appear.

Eckert, C., Clarkson, P.J., and Zanker, W., 2004. Change and customisation in complex engineering domains. *Research in Engineering Design*, 15 (1), 1–21.

Eckert, C., Stacey, M., and Earl, C., 2013. Formality in design communication. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, 27 (02), 91–103.

Eckert, C.M. and Clarkson, P.J., 2002. Planning Design Processes in Industry: Initial Observations. *Proceedings of EDC*, 2, 637–646.

Eckert, C.M. and Clarkson, P.J., 2010. Planning development processes for complex products. *Research in Engineering Design*, 21 (3), 153–171.

Eckert, C.M., Clarkson, P.J., and Stacey, M.K., 2001. Information flow in engineering companies: problems and their causes. *In*: *International Conference on Engineering Design*. 43–50.

Eckert, C.M., Stacey, M., Wyatt, D., and Garthwaite, P., 2012. Change as little as possible: creativity in design by modification. *Journal of Engineering Design*, 23 (4), 337–360.

Ehrlenspiel, I.K., Giapoulis, A., and Günther, J., 1997. Teamwork and design methodology—Observations about teamwork in design education. *Research in Engineering Design*, 9 (2), 61–69.

Eisenhardt, K.M., 1989. Building theories from case study research. *Academy of management review*, 532–550.

El-Tayeh, A., Gil, N., and Freeman, J., 2008. A methodology to evaluate the usability of digital socialization in "'virtual'"engineering design. *Research in Engineering Design*, 19 (1), 29–45.

Eppinger, S.D., Nukala, M. V., and Whitney, D.E., 1997. Generalised Models of Design Iteration Using Signal Flow Graphs. *Research in Engineering Design*, 9 (2), 112–123.

Flanagan, T., Eckert, C., and Clarkson, P.J., 2007. Externalizing tacit overview knowledge: A model-based approach to supporting design teams. *AI EDAM-Artificial Intelligence Engineering Design Analysis and Manufacturing*, 21 (3), 227–242.

Flyvbjerg, B., 2006. Five Misunderstandings about Case Study Research. *Qualitative Inquiry*, 12 (2), 219–245.

George, A.L. and Bennett, A., 2005. *Case Studies and Theory Development in the Social Sciences*. MIT Press.

Gil, N., Tommelein, I.D., and Beckman, S., 2004. Postponing design processes in unpredictable environments. *Research in Engineering Design*, 15 (3), 139–154.

Gold, R.L., 1997. The ethnographic method in sociology. *Qualitative inquiry*, 3 (4), 388–402.

Hess, T.A., 2012. Investigation of Prototype Roles in Conceptual Design Using Case Study and Protocol Study Methods. Clemson University.

Hess, T.A. and Summers, J.D., 2013. Case Study: Evidence of Prototyping Roles in Conceptual Design. *In*: *Inernational Conference on Engineering Design*. Seoul, South Korea: The Design Society, no. 204.

Jagtap, S. and Johnson, A., 2011. In-service information required by engineering designers. *Research in Engineering Design*, 22 (4), 207–221.

Jarratt, T., Eckert, C., and Clarkson, P.J., 2006. Pitfalls of Engineering Change. *In*: *Advances in Design*. Springer, 413–423.

Keraron, Y., Bernard, A., and Bachimont, B., 2009. Annotations to improve the using and the updating of digital technical publications. *Research in Engineering Design*, 20 (3), 157–170.

Kloss-Grote, B. and Moss, M.A., 2008. How to measure the effectiveness of risk management in engineering design projects? Presentation of RMPASS: a new method for assessing risk management performance and the impact of knowledge management—including a few results. *Research in Engineering Design*, 19 (2-3), 71–100.

Legardeur, J., Boujut, J.F., and Tiger, H., 2010. Lessons learned from an empirical study of the early design phases of an unfulfilled innovation. *Research in Engineering Design*, 21 (4), 249–262.

Lloyd, P. and McDonnell, J., 2009. *Introduction to about: designing-analysing design meetings*. Taylor and Francis Group.

López-Mesa, B. and Bylund, N., 2011. A study of the use of concept selection methods from inside a company. *Research in Engineering Design*, 22 (1), 7–27.

Martin, P.Y. and Turner, B.A., 1986. Grounded theory and organizational research. *The Journal of Applied Behavioral Science*, 22 (2), 141–157.

McComas, W.F., 2002. The principal elements of the nature of science: Dispelling the myths. *In*: *The nature of science in science education*. Springer, 53–70.

Newstetter, W.C., 1998. Of green monkeys and failed affordances: A case study of a mechanical engineering design course. *Research in Engineering Design*, 10 (2), 118–128.

Palmer, G. and Summers, J.D., 2011. Characisterization of Leadership within Undergraduate Engineering Design Teams through Case Study Analys. *In*: *International Conference on Engineering Design 2011, Copenhagen, Denmark*. No–204.

Pask, G., 1976. *Conversation theory*. Citeseer.

Pasqual, M.C. and De Weck, O.L., 2012. Multilayer network model for analysis and management of change propagation. *Research in Engineering Design*, 23 (4), 305–328.

Rexfelt, O., Almefelt, L., Zackrisson, D., Hallman, T., Malmqvist, J., and Karlsson, M., 2011. A proposal for a structured approach for cross-company teamwork: a case study of involving the customer in service innovation. *Research in engineering design*, 22 (3), 153–171.

Reymen, I., Hammer, D.K., Kroes, P.A., Van Aken, J.E., Dorst, C.H., Bax, M.F.T., and Basten, T., 2006. A domain-independent descriptive design model and its application to structured reflection on design processes. *Research in Engineering Design*, 16 (4), 147–173.

Romero, F., Agost, M.-J., and Vila, C., 2008. Activity modelling in a collaborative ceramic tile design chain: an enhanced IDEF0 approach. *Research in Engineering Design*, 19 (1), 1–20.

Rowley, J., 2012. Conducting research interviews. *Management Research Review*, 35 (3/4), 260–271.

Shankar, P., 2012. Development of a design method to reduce change propagation effects. Clemson University.

Shankar, P., Morkos, B., and Summers, J.D., 2012. Reasons for change propagation: a case study in an automotive OEM. *Research in Engineering Design*, 23 (4), 291–303.

Stacey, M. and Eckert, C., 2003. Against ambiguity. *Computer Supported Cooperative Work (CSCW)*, 12 (2), 153–183.

Stowe, D., Conger, K., Summers, J.D., Joseph, P., Thompson, B., and Matthews, J., 2008. Designing a lunar wheel. *In*: *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*. Brooklyn, NY: ASME, ATTV–49981.

Stowe, D., Thoe, S., and Summers, J.D., 2010. Prototyping in Design of a Lunar Wheel - Comparative Case Study of Industry, Government, and Academia. *In*: *Aeronautical Industry in Queretaro Conference*. Queretaro, Mexico: SAE.

Stowe, D.T., 2008. Investigating the Role of Prototyping in Mechanical Design Using Case Study Validation. Clemson University.

Tahera, K., Earl, C., and Eckert, C., n.d. Integrating physical and virtual testing to improve confidence in product design. *IJTM*.

Teegavarapu, S., 2009. Foundations of design method development. Clemson University.

Teegavarapu, S., Summers, J.D., and Mocko, G.M., 2008. Case study method for design research: A justification. *In*: *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*. Brooklyn, NY: ASME, DTM–49980.

Tribelsky, E. and Sacks, R., 2010. Measuring information flow in the detailed design of construction projects. *Research in Engineering Design*, 21 (3), 189–206.

Veldman, J. and Alblas, A., 2012. Managing design variety, process variety and engineering change: a case study of two capital good firms. *Research in Engineering Design*, 23 (4), 269–290.

Vianello, G. and Ahmed, S., 2012. Transfer of knowledge from the service phase: a case study from the oil industry. *Research in Engineering Design*, 23 (2), 125–139.

Walton, D.N. and Krabbe, E.C.W., 1995. *Commitment in dialogue: Basic concepts of interpersonal reasoning*. SUNY press.

Wasiak, J., Hicks, B., Newnes, L., Dong, A., and Burrow, L., 2010. Understanding engineering email: the development of a taxonomy for identifying and classifying engineering work. *Research in Engineering Design*, 21 (1), 43–64.

Wilcox, B.H., Litwin, T., Biesiadecki, J., Matthews, J., Heverly, M., Morrison, J., Townsend, J., Ahmad, N., Sirota, A., and Cooper, B., 2007. ATHLETE: A cargo handling and manipulation robot for the moon. *Journal of Field Robotics*, 24 (5), 421–434.

Wyatt, D.F., Eckert, C.M., and Clarkson, P.J., 2009. Design of Product Architectures in Incrementally Developed Complex Products. *In*: *Proceedings of the 17th International Conference on Engineering Design (ICED'09), Vol. 4*. 167–178.

Yin, R., 2003. *Case Study Research: Design and Methods*. Thousand Oaks, CA: Sage.

Zika-Viktorsson, A. and Ritzén, S., 2005. Project competence in product development. *Research in Engineering Design*, 15 (4), 193–200.