

## DESIGN AS THE RESOLUTION OF PARADOXES: AN EXPLORATORY STUDY

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### Abstract

This paper presents an ethnomethodological case study of a student engineering design team during their final year design project. The results were analysed with reference to a theoretical framework, based on Dorst's (2006) model, in which "a 'design problem' is taken as a paradox, made up out of the clash of conflicting discourses" and "the nature of creative design is the forging of connections between these discourses". Three key discourses emerged from the data, that of the 'commercial sponsor', the 'university', and the 'student group'. It is suggested that the 'commercial sponsor' and 'university' discourses were in conflict, forming the 'central paradox' at the heart of the design problem. The student group failed to resolve this paradox, and went on to significantly underachieve in their design project.

The aim of this research was to explore and describe the complex ways in which design emerges in practice, using Dorst's model of design problems as a theoretical framework. The framework has proved a useful and insightful way of considering how design occurs naturally in interactions between people.

**Keywords:** Ethnomethodology, Human behaviour in design, Design problems

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## 1 INTRODUCTION

The study of human behaviour plays an important part in developing our understanding of design. It is the inherently human aspects of designing; emotion, subjectivity, and social interaction, that make designing possible, and yet make the study of design so difficult. The research outlined in this paper explores design in a natural setting using ethnomethodology, and a theoretical framework based on Dorst's model of design problems (Dorst 2006). Specifically the paper presents the results of an exploratory case study of a student engineering design team, as they completed their final year design project. The purpose of this study was to try to uncover insights about the fundamental nature of designing, by studying the interactions between designers, paying particular attention to their talk. The basic premise of the research is that the better we understand design, the better we can design.

Section 2 of this paper gives an overview of current thinking on the nature of design problems, and describes Dorst's model. Section 3 outlines the ethnomethodological approach used in this research, and Section 4 describes the particular context of the case study. In section 5 the case study findings are presented, and then discussed in section 6. Finally, the paper concludes in section 7.

## 2 DESIGN PROBLEMS

Design problems, and the context they arise in, are often unique. In order to learn something about the problem at hand, it is usually necessary to begin by exploring its possible solution. This is a way of partially bounding an otherwise open-ended (and therefore unsolvable) problem. By applying various context-appropriate constraints as a kind of experiment, much can be learned about the nature and structure of the problem. Darke (1979) has termed this initial exploratory solution the 'primary generator'. Schön (1983) describes this activity as 'framing', part of a "reflective conversation with the situation" in which "the designer constructs the design world within which she sets the dimensions of her problem space, and invents the moves by which she attempts to find solutions". Design is not merely technical problem-solving, design is about situated problem-setting. Through these various processes the problem and solution 'co-evolve' together, with gradual bridging occurring between problem and solution spaces (Dorst and Cross 2001). This natural evolution of design enables the possibility of holistic, integrated and coherent solutions, in which many, often conflicting requirements can be met by a single idea. Dorst and Cross conclude that "creative design is not a matter of first fixing the problem (through objective analysis or the imposition of a frame) and then searching for a satisfactory solution concept. Creative design seems more to be a matter of developing and refining together both the formulation of a problem and ideas for a solution, with constant iteration of analysis, synthesis, and evaluation processes between the two notional design 'spaces'". The result is a matching problem-solution pair. This would suggest that there is actually no distinct and definable 'design problem' to be found anywhere within the design process, other than in relation to the final solution.

So, if design cannot be described in terms of conventional problem-solving, and design problems are very special kinds of problems that don't fully manifest themselves until solved, how are we to proceed in methodological terms towards an understanding of design? How can design problems be modelled? Dorst (2006) describes 'new' approaches to modelling design problems, such as 'situated problem-solving'. Seen from this perspective, the design problem "does not really exist as an objective entity in the world". Instead the design problem is highly context specific, depending on both the viewpoint of the designer and the particular design situation. The focus here is on a 'local' design problem. It is "an amalgamation of different problems centred on the basic challenge described in the design brief". Another key aspect of situated problem-solving is that 'real' design is considered only to happen during a breakdown in the normal problem-solving process, brought about by conflicting constraints, that represents a moment of genuine choice. What we mean here is that for large parts of the design process no real design is occurring at all; rather it is mainly routine, conventional problem-solving (applying existing solutions to defined problems). Hatchuel (2001) suggests that the majority of any design project includes this kind of problem-solving, but that design itself cannot be reduced to problem-solving. There are other processes at play.

Dorst (2006) has proposed a model in which he specifies the fundamental nature of design problems: "A 'design problem' is taken as a paradox, made up out of the clash of conflicting discourses", and "the nature of creative design is the forging of connections between these discourses, on a general level or in the concrete design". Dorst defines 'paradox' here as "a complex statement that consists of

two or more conflicting statements”. The discourses are the “elementary statements that make up the paradox, and the viewpoints and ways of thinking that underlie these statements”. For example discourses may relate to technology, form, or aesthetics – what Dorst refers to as the ‘aspects’ of a design, or they may relate to the different stakeholder roles and their value systems. Therefore the “creation of a solution to the paradoxical design situation thus also becomes a social process”. Ultimately the design solution must somehow resolve or transcend these conflicting discourses. Elsewhere, Lawson [2006] describes design problems as ‘multidimensional and highly interactive’. He proposes that “a design solution is an integrated response to a complex multidimensional problem” and that it is the ‘interconnectedness’ of these factors at the very core of design problems. This seems to support Dorst’s notion of design problems as “the resolution of paradoxes between discourses in a design situation”. We can perhaps conclude, therefore, that it is the conflicts, and the connections between them, in highly situated and subjective contexts, that characterise design problems. Resolving these multidimensional conflicts or ‘paradoxes’ in an integrated and holistic way may play an important role in design. For Dorst [2011] the ‘core’ of design thinking lies in the way in which designers engage with the ‘central paradox’ of a problem situation. He suggests that designers focus on establishing this central paradox before beginning any attempts at solution conjecture. Interestingly, the study carried out by Dorst shows that expert designers tend to use a phenomenological approach to this analysis, by searching the broader problem context for clues, or ‘themes’, rather than tackling the central paradox head-on. These ‘themes’ provide a way of understanding the underlying issues relating to the central paradox, so new frames can then ‘emerge,’ which re-cast the paradox in original and unexpected terms. Or as Dorst puts it, they “inform the development of a frame that articulates a response to the central paradox of the problem situation.”

### **3 ETHNOMETHODOLOGY**

Ethnomethodology is the study of the everyday practices and organisational structures used by people within a particular social group. It is a qualitative research method used for exploring cultural phenomena through sociological inquiry. Ethnomethodology finds its roots in pure ethnography, but later developed by Harold Garfinkel [1967] within the subject of sociology, it is a form of inquiry that may be applied in any social setting, such as a place of work, or local neighbourhood. It is also a way of collecting and analysing rich social data without application of prior theory. The intention is not to prove or disprove a particular hypothesis, or to quantify a particular phenomenon. Any theory should be generated directly from the data itself. The goal is an understanding of the *nature* of phenomena.

Many different data collection techniques may be used in ethnomethodology, including primary techniques such as participant observation, field notes, interviews, or surveys. Secondary techniques such as document analysis may also be used. Participant observation requires the researcher to share in the naturalistic setting, daily activities, rituals, interactions, language, social relations, and events of a particular group of people, in order to learn about its social order. This cultural immersion should enable the researcher to generate an accurate, meaningful, and insightful account of the social group being studied.

In ethnomethodological research, data analysis is most commonly done by ‘coding’ into categories or ‘themes’ which emerge naturally from the data. This is done by attaching labels to sentences or words in the field notes or transcribed text, and looking for patterns in the way the labels are organised. DeWalt [2010] suggests that “developing and applying categories and codes is not an aid to analysis, it is analysis. It is the principle tool we use to build theories and arguments drawn from the data”. Once the data has been reduced in this way, it can be displayed in the form of vignettes, cases, or quotes.

#### **3.1 Ethnomethodology for design research**

The complex realities of commercial design practice mean that it may not be viable to perform controlled experiments within a real world setting. Yet research outside of a real world setting will always suffer from a fundamental lack of validity. Any empirical technique used within the real-world of design practice must also be able to capture the informal and adhoc interactions that occur outside of scheduled meetings. It must also fully embrace the intrinsically social nature of designing. Ethnomethodology has the capacity to capture the richness of design in this way. The importance of this method has been clearly demonstrated by the steadily increasing number of ethnomethodological studies published over the last two decades. Most notably since the seminal work of Bucciarelli

(1988), that explored design as a social process. These studies have been undertaken in many different design contexts, from engineering design to graphic design (Lloyd & Deasley (1998), Lloyd & Busby (2001), Tan & Melles (2010)). They have highlighted the fact that commercial design is collaborative, highly social, and centred around ‘talk’. Ethnomethodology therefore shifts our stance away from a positivist to a constructivist world view of design, by focusing on the richness of design in practice as a way of understanding how designers creatively shape and respond to highly specific design contexts. According to Luck (2012) ethnomethodology explores the ‘distinctiveness’ of design situations, and suggests that “in ethnomethodological enquiry it is not ‘thinking’ as a mental process that is witnessable in a sequence of actions, but what it is that a sequence of actions accomplishes”. In other words it is not the thought processes of designers that we are interested in uncovering using ethnomethodology, but how their talk and interactions directly create design.

## **4 CASE STUDY**

### **4.1 Theoretical framework**

The results of this study have been analysed with reference to a theoretical framework provided by Dorst’s model (Dorst 2006), in which “a ‘design problem’ is taken as a paradox, made up out of the clash of conflicting discourses” and “the nature of creative design is the forging of connections between these discourses”. This framework is based on the following definitions provided by Dorst:

- A ‘paradox’ is defined as “a complex statement that consists of two or more conflicting statements”
- The ‘discourses’ are the “elementary statements that make up the paradox, and the viewpoints and ways of thinking that underlie these statements”.
- The discourses may relate to ‘aspects’ of the design, such as technology, form, or aesthetics, or they may relate to the different stakeholder roles and their value systems.

In his 2006 paper on design problems and paradoxes, Dorst proposes that “the next task we then encounter in the quest to really understand design is [...] to define the structure of the discourses”. He also suggests that “the model needs to be extended further by defining the link between the notion of discourses and the ‘aspects’ of a design, the stakeholders involved in the project, and the designers level of expertise”. In this paper we have tentatively tried to take up this challenge, or at least begin to explore some of these ideas further. An exploration of design expertise in relation to Dorst’s model is beyond the scope of this particular study, but does form part of the wider ongoing research project.

The aim of this research was to explore and describe the complex ways in which design emerges in practice, using Dorst’s model of design problems as a theoretical framework.

An exploratory study has been carried out in order to achieve this aim. The purpose of the exploratory study was to identify key themes and patterns in the data. This has been done using ethnomethodological analysis techniques in order to produce a written ethnography. Only the initial findings are presented in this paper. A full ethnography will be published at a later date.

### **4.2 Study context, data collection & analysis**

Undergraduate engineering design students at Bristol University are required to undertake team design projects in their fifth (and final) year. The fifth year data was chosen for this study because this design group represent an approximate midway point in the development of expertise. They were in their final year of study and had already spent a ‘sandwich’ year working in industry as part of their degree programme. The design project undertaken by the fifth year group was also a quasi-real project. The original design brief was developed in partnership with a major engineering design consultancy (referred to as ‘Design Co’ in this paper), with the aim of producing genuinely usable outcomes for the company. The project was also co-supervised by a representative from Design Co. It was hoped that this midway, quasi-real aspect of the design project would reveal the widest variety of themes, including those that relate to educational aspects of design, as well as real-world commercial design.

The students undertook group project design work over approximately 20 weeks. This research project followed one student group, containing 4 students; 3 male and one female. We shall refer to them here as Simon, Jim, Toby, and Clara. None was a mature student. The group had regular interactions with their university project advisor (Hugo), a university industrial liaison (George), and a representative of Design Co (Anna) (not real names). Primary data was gathered through video recording of the group

undertaking design work. Data analysis was conducted as outlined in the previous section, using NVivo coding software.

The final year project was intended to build on work done previously in their fourth year project (a city bike-scheme), done in conjunction with the same commercial sponsor (Design Co). However, the student group opted to reject their fourth year work, (on grounds a bike-scheme in Bristol was not commercially viable) and start again with a new project, with no set brief. Below is an excerpt from the completed final (fifth) year design project report abstract, written by the students and submitted at the end of the design project. It outlines their final design:

*“Key concepts behind Smart Scheme operation were investigated in order to identify the source of value in Smart Schemes. [...] Through this prior knowledge, a process to generate a value case for any Smart Scheme in any city was established. This report details a general framework, known as the Smart Scheme Value Assessment (SSVA) process, which identifies what inputs are required, what processes would be necessary, and what the outputs are. Secondly a selection of tools to address each stage of the process were devised, or identified from standard industry tools. The result is a general methodology for producing a value case for a Smart Scheme”.*

## **5 RESULTS**

The results are presented here in the form of notes and quotations taken from 8 design meetings conducted by the student group. For some meetings Hugo (university project advisor), George (university industrial liaison), and/or Anna (Design Co representative) were also present. These results represent only a small proportion of the total data collected, but they have been chosen in order to convey the basic project narrative and highlight the key themes.

### **Meeting 1 (All students plus Hugo, George, and Anna)**

The group are meeting with all parties for the first time to discuss the start of the fifth year project. Clara explains that they want to define the scope of their ‘new’ project in relation to the government’s ‘TSB (Technology Strategy Board) Future Cities Demonstrator’ initiative, which Design Co is bidding for. Clara says they want to align themselves more with Design Co’s current situation “looking at the use of data and hopefully feeding information back into Design Co, and the City Council”.

Anna explains that Design Co are very much focusing on the transport side of smart cities, but call it ‘mobility’ to include a wider scope. In a nutshell, to “aggregate data and use it to create wider economic value”. Anna suggests the student group uses IBMs new list of data streams within the city to “create an architecture to manage the data, to create value for the city”. Simon responds “I’m not exactly sure if this is too broad. I’m slightly concerned that in six months we’ll end up with no real deliverable”. George agrees, he points out they are “design engineers, not computer scientists”. They should be a step below the level Design Co is working at; they should be the “nuts and bolts”. Hugo suggests they “focus on something specific”, something they could track. He’s also worried it’s too broad.

The students discuss having a ‘black box’ on a bike that collects data. George wants to know “if you treat the device as a black box, what are you actually going to *do* (for the project)?” Clara says if they think about what they can actually do with the data, and how it could align with Design Co and their initiatives, they could then work out what data was actually required...“work their project backwards from what Design Co and the City Council want”. Jim is worried they’ll have a load of great ideas but no concrete deliverable if they focus on a device, that the group doesn’t have enough “know-how”.

George says “I think you guys are trying to run before you can walk. This is what the government are doling out £24 million for (TSB initiative)... to solve a problem that you guys are trying to solve in 20 weeks. I’m concerned.” “Forget Design Co” he says, “I’m just concerned that you work in such a way that you get a very high mark. That’s my primary concern. Keeping Design Co on side is a secondary concern. They’ve got all sorts of other things in the pipeline”.

George asks Toby about bike hardware i.e. building or converting a bike, putting sensors and communications technology on it. Toby doesn’t seem sure how they could do this. Simon says “I’m far more interested in the part of the project where we look at the information we have and what its value is, which is probably why I’m less interested in the electronics, because that’s the bit I want to do. Through the whole of last year I was constantly looking back at revenue sources, value, and things like that. So in my mind that’s where I see this project going”. Simon asks if any of the other members

would be interested in doing the hardware side of things. Jim says none of them know enough to do it on their own.

### **Meeting 2 (All students)**

The group are holding a meeting to brainstorm potential design problems they might tackle for the project. They begin by discussing their personal project objectives. Toby says “getting a high first”, Clara says “ideally something that would be applicable to our jobs next year”, and Simon adds “use our own skills”. Simon suggests that they “target smart cities and something related to mobility...that in essence is what Design Co want us to do”. Simon adds “although we’re doing this to get good marks, and that’s an objective, it’s certainly an objective to keep on Design Co’s good side, simply because then we get better support from them. If Anna is interested in what we’re doing, if it benefits her to help us...I don’t think...if she’s not interested....she’s got quite a lot on, and would probably be quite happy to let us do our own thing”. Clara replies “she doesn’t like technical stuff, she likes her strategy.”

After discussing various possible design problems to focus on for the project, Toby says “the main problems I feel we’re missing are from, like, the Design Co side. So I know we’ve looked at the Council side...but when Anna was talking to us, the two main things she was talking about was ...how to collect data from a city...what can you actually do with all that data? It’s the use of it as well”

They discuss Design Co’s objectives, including ‘transferability’ of design solutions to other cities. Simon suggests they should make themselves “invaluable” to Design Co with a view to getting a job afterwards. Jim points out that this could be in conflict with their main objective, which is to get ‘firsts’. Simon responds “how many projects have you come across where all of the objectives line up?”

After further discussion on several possible design problems, Simon comes up with “not knowing enough about your own city to be able to plan a bike scheme before implementing it. The solution would be to have a bike with sensors on to understand how bikes move around a city”. Toby says “or you could make it more generic...a criteria, or a selection process, to allow cities to determine whether or not...what size of bike scheme... or whether a bike scheme would be successful.”

Jim muses “the problem with these problems is that all the solutions require us to look at, like, policy...it means we have to put things in our report, which are like these ‘ideas’ things, rather than the engineering side.” He suggests they need to find some technical aspect of their project to focus on, to come out at the end “with something really concrete”. Simon agrees “we could easily come out having made no conclusions whatsoever, looking like we spent the whole year doing nothing”. Toby adds “or not having enough solid proof”. Simon points out “one of the requirements (of the project) is that we have quantitatively analysed something, and it’s pretty hard to quantitatively analyse government policy”. The discussion moves on to other potential design problems, including ‘automation of traffic control rooms’, Toby is worried that this problem could result in an overly technical project that he wouldn’t understand. Simon considers their list of potential design problems and says “shall we do one on bikes (hardware)?” Jim says “yeah, I think George is still really keen on that idea”.

### **Meeting 3 (All students)**

The group are preparing a preliminary report they must submit to the university, outlining their objectives, concept design, and project plans. Toby, on whether to follow the university guidance for the preliminary report or not, says “we’ve always done it our own way, because we’re encountering our own problems as a group, and we haven’t worried too much about what other people are doing, or strictly what we’ve been told we should do, and I think we should keep that up because we need to make sure we just keep on... we’re on the right path and we need to make sure we keep running down it”.

Toby also says they need to understand Design Co better. He suggests “Design Co are our major stakeholder, so we should define the project requirements from Design Co’s point of view. What Design Co wants is quite open”. The group discuss the project requirements; Jim adds “another must is that it (the project deliverable) must be transferable to other cities”.

### **Meeting 4 (All students plus Hugo)**

The students are meeting with Hugo to discuss the preliminary report, and project progress. Hugo talks about needing a practical demonstration of their project. He says that without it their project will be

too 'high level', 'theoretical', and 'unproven'. The group discuss how they might do this. They have decided to collect real data by riding their own bikes, fitted with sensors, around Bristol. This is intended to provide proof-of-concept on the practicalities of data collection, and how this data might be used (e.g. GIS modelling).

Later Jim clarifies with Hugo "So as an overview you're happy with the report, and our intentions of what it's saying?" Hugo says "yeah, yeah. If you work on the few things (the practical demonstration)..."

#### **Meeting 5 (All students)**

The group are meeting to update each other on work they've been doing individually. Jim refers to the "wishy washy" sociology stuff he's been reading in some reports "which is an important aspect, but is that stuff actually relevant to what we're doing?" he asks "or whether literally we're just saying 'cities exist', 'they are a system', 'they have the following properties'". Clara says "it depends what our deliverable actually is doesn't it? What is our deliverable?" Jim replies "well it's... a plan... a smart cities plan, that's what I thought we were saying". They discuss. No-one seems sure. Toby says "I thought our deliverable was some sort of proof of data value... an overall of smart cities with some sort of quantifiable value of data with a case study, or an example bike scheme being used for that collection."

#### **Meeting 6 (All Students plus Hugo and Anna)**

The students are preparing for a catch-up meeting with Hugo and Anna, who are joining them later. Toby checks "are we making it really clear what we're planning to do, I'm not sure others will understand what it is?" Clara says "I'm not sure I understand!"

(Anna and Hugo arrive) Clara explains that this is an update meeting. Toby starts "I can't really remember where we left you guys or what your amount of understanding is of what we're trying to achieve?" Anna replies "I haven't really spoken to you this entire year, since the meeting we had at Design Co at the beginning (meeting 1), so I don't really know what your project is." Toby explains the project. That they looked at the fourth year brief of a bike scheme, and decided it wouldn't be beneficial. So they took a new approach... "you have a smart system which collects the data, get the data, some sort of processing of it adds value, and then there's some sort of feedback loop into the smart system. So we looked at that cycle, and realised that first of all people didn't really understand where the value was coming from in that data, or how to collect that data, a real bottle neck around the data itself, and that starting from the smart scheme and defining that in detail wasn't useful. We needed to start at the data itself. What we're now doing is a mix of defining a smart scheme and collecting data ourselves. We're proving the smart cities concept as a whole. That's the overview as I see it". Anna says "ok", silence, "How're you doing that?" Jim says "the way we're trying to justify it as well, obviously... the government (TSB Future Cities Demonstrator) just want industry that they can export, rather than just... it's not just that we want our cities to be better, we want our cities to apply these concepts, get really good at it... then we can just sell it overseas. So the... idea was... instead of just applying it to somewhere like Bristol, we try and get the concepts at quite a generic level, so we've got an exportable model." Anna asks what the 'end thing' is that they're going to come up with. Clara jokes "I've absolutely no idea... it's a kind of 'how to guide'".

#### **Meeting 7 (All students)**

The group are holding a progress meeting. Toby says "basically the process for developing your smart scheme and implementing it, within your city... so it's like our main deliverable I guess. I assume from that we develop all the tools and information we need, so we kind of build outwards from that?!" Simon responds "I think all these tools that we've used to actually do the project kind of... I think they might actually come out quite well, because it's..." Jim joins in "it'll look good... stick 'em in our report... it's a whole process, a design process". Clara adds jokingly "suddenly we have a systems engineering (project)..." Jim also jokes "shall we say we had, like, 'gates'?"

#### **Meeting 8 (All students plus George)**

The students are meeting with George to discuss their draft final report. George explains to the group that "it was difficult for me to understand what you meant... I think if you'd given some examples as you went through to ensure that what you meant..." George continues "what I'm commenting really is make sure you don't lose somebody's understanding. If I can be a bit critical... the words are a bit

management consultancy-like”. Toby explains this is because they were trying to make it very “textbook”. George says it’s important they’re doing this i.e. not just a bottom up approach, trying to back it up with theory. Clara asks “which terminology doesn’t make sense? We’ve tried to define...” George reassures her “no I thought it was good, it was just a slight touch of...which textbook have they got this out of...because it lacked evidence in the application”. Simon explains that because they’ve invented the process themselves, it maybe isn’t as rigorously defined as it should be. Jim explains how people don’t really understand how to find the value in smart cities, so that’s their solution. Simon adds “we’re also trying to be as generic as possible...we really want it to be possible to apply this to any scheme....doesn’t even have to be a transport scheme. We’re trying to keep the terms broad”.

George asks “where does the physical hard side of the engineering fit in? I know you’ve got sensors used and ridden bikes around the town...” Simon “yeah we’ve done that...what we’ve started to do is mapping bike user data onto GIS.” Jim explains GIS to George, and they show him their GIS model.

George asks “where do you guys think you’re going to get to by the report submission?” Simon replies “what we’re looking at is ...we have this process relatively well established...to look in detail at models which could be used to actually do any of the phases in real life. A small-scale application to Bristol, demonstration of data collection, making some conclusions from this data... and also talk about the exportability of the model”. Clara adds “so its limitations and transferability....the key thing that Design Co is interested in is its transferability”. George says “does that go into the business case?” Jim replies “yeah, that’s a big part of why the government is putting funding into it, they want a business they can export, but essentially what we’re building up is a tool-kit that you use, and this is how you go about it”.

George asks about their presentation “how’re you going to constrain the massive amount of stuff you’ve done?” Toby says “we don’t really have any requested deliverables... we’re working through this process... it’s really likely there’ll be some modelling like this... it’s a tool-box, but we can’t say what the tools will be until we develop them, so we can’t say what we’ll be presenting”. George says he’s happy with progress and leaves the meeting.

Clara says “he seemed happy”. Simon agrees “yeah, I think he really liked it, which is very good”. Toby asks “are you surprised?” Clara says “yeah!” Simon adds “I thought that was really good though, the fact that George doesn’t seem terrified that we’ve done nothing...he seems to find what we’re doing...and actually like the fact that it’s not...he’s happy with the amount of pure engineering we’re doing”.

## 6 DISCUSSION

By their own standards the group did not achieve highly in their design project. They set themselves the personal objective of “getting high firsts” (UK ‘first’ usually equivalent to over 70%). As a group they scored rather lower than this, coming bottom out of all student groups that year. Assessment feedback suggested that their project was ‘too broad’, ‘high level’, ‘confusing’, had ‘poor requirements formulation’, and ‘lacked technical (engineering) content’. In this section we will explore the possible factors contributing to this underachievement, using Dorst’s model as a theoretical framework.

Analysis of the data has revealed many potential ‘design discourses’ within the project, some relating to the ‘aspects’ of the design, including (but not limited to) data streams, smart city technologies, sensors, bikes, databases, GIS modelling, communications networks, and systems architectures. However, it was felt that these discourses did not play a major role in the poor design outcome of the group, and therefore fall outside the scope of this paper. Further discourses identified relate to the roles and values of stakeholders in the project. The three main discourses that will be discussed here are; the ‘university’, the ‘commercial sponsor’, and the ‘student group’ discourses. These discourses are revealed in conversations between the student group, the university project advisor (Hugo), university industrial liaison (George), and the commercial sponsor representative (Anna).

The ‘**university**’ discourse can be characterised as ‘hard’ engineering focused, quantitative, concerned with concrete deliverables, narrow in scope, hands-on level of design. Evidence for this can be found in the interactions that George and Hugo have with the group. In meeting 1 they both dismiss Anna’s suggestion of designing a “data management architecture” as too broad. George reminds the students that they are “design engineers, not computer scientists” and their project should be the “nuts



and bolts” level of design. Hugo suggests that they “focus on something specific”. George is also concerned with their ‘black box’ device idea...“what are you actually going to *do*” he says, and then later “I think you guys are trying to run before you can walk”, “forget Design Co”, “I’m just concerned that you work in such a way that you get a very high mark”. In meeting 4 Hugo is worried that their project is too “high level”, “theoretical”, and “unproven”, and suggests they need a “practical demonstration” of their ideas. In the final meeting, having read their draft final report, George asks the students: “where does the physical hard side of the engineering fit in?”

The ‘**commercial sponsor**’ discourse can be characterised as value focused, qualitative, concerned with transferable deliverables, broad in scope, dealing with high level design. Evidence for this can be found in the interactions the group have with Anna, for example in meeting 1 when she summarises Design Co’s main focus as “aggregate data and use it to create wider economic value”, and suggests the group uses IBMs new list of data streams within the city to “create an architecture to manage the data, to create value for the city”. The Design Co discourse has been strongly influenced by the government ‘TSB Future Cities Demonstrator’ initiative, which Design Co is bidding for funding from. In meeting 2 Simon suggests that they “target smart cities and something related to mobility...that in essence is what Design Co want us to do”, and later Toby says “when Anna was talking to us, the two main things she was talking about was like...how to collect data from a city...what can you actually do with all that data? It’s the use of it as well”. In meeting 3, identifying a key objective of Design Co, Jim says “it must be transferable, to other cities”. In meeting 6 Jim ‘sells’ their project to Anna... “the way we’re trying to justify it as well, obviously... the government (TSB initiative) just want industry that they can export, rather than just...it’s not just that we want our cities to be better, we want our cities to apply these concepts, get really good at it...then we can just sell it overseas. So the... idea was...instead of just applying it to somewhere like Bristol, we try and get the concepts at quite a generic level, so we’ve got an exportable model.”

The ‘**student group**’ discourse can be characterised as high achieving/aspiring, value-focused, and ‘hard’ engineering averse. Evidence for this can be found in the interactions the group have with each other. For example, in meeting 2 the group discuss their personal objectives, Toby says “getting a high first”, Clara says “ideally something that would be applicable to our jobs next year”, and Simon adds “use our own skills”. This last objective links to a certain reluctance the group show to tackle anything too technical. For example, in meeting 1 Jim is worried the group doesn’t have enough “know-how” to design a data collection device themselves, and Toby doesn’t seem sure how they could build or convert a bike to put sensors and communications technology on it. Simon says “I’m far more interested in the part of the project where we look at the information we have and what its *value* is, which is probably why I’m less interested in the electronics, because that’s the bit I want to do”. When Simon asks if any of the other members would be interested in doing the hardware side of things, Jim suggests none of them know enough to do it on their own. In meeting 2 Toby is worried that tackling the ‘automation of traffic control rooms’ design problem could result in an overly technical project that he wouldn’t understand.

The students do appear to acknowledge the ‘university’ discourse at various points, for example in meeting 2 Jim says “the problem with these problems is that all the solutions require us to look at, like, policy...it means we have to put things in our report, which are like these ‘ideas’ things, rather than the engineering side” and Simon adds “one of the requirements (of the project) is that we have quantitatively analysed something, and it’s pretty hard to quantitatively analyse government policy”. When Simon considers their list of potential design problems and says “shall we do one on bikes?” Jim says “yeah, I think George is still really keen on that idea”. In the next meeting however, they dismiss the university guidance for the preliminary report “we’ve always done it our own way, because we’re encountering our own problems as a group, and we haven’t worried too much about what other people are doing, or strictly what we’ve been told we should do, and I think we should keep that up...”. Though later, in meeting 5, Jim questions where their project now sits, (in the context of the different discourses), when he refers to the “wishy washy” sociology stuff he’s been reading in some reports “which is an important aspect, but is that stuff actually relevant to what we’re doing?” he asks “or whether literally we’re just saying ‘cities exist’, ‘they are a system’, ‘they have the following properties’”. Clara says “it depends what our deliverable actually is doesn’t it? What is our deliverable?” In meeting 7 they seem to recognise the ‘university’ discourse in relation to their project report, when Simon says “I think all these tools that we’ve used to actually do the project kind of...I think they might actually come out quite well, because it’s...” Jim joins in “it’ll look good... stick ‘em

in our report...it's a whole process, a design process". Clara jokingly adds "suddenly we have a systems engineering (project)..." Jim also jokes "shall we say we had, like, 'gates'?!"

From the very first meeting the group align themselves to Design Co's discourse. Clara explains they want to define the scope of their project in relation to the TSB Demonstrator, and to align themselves more with Design Co's current situation "looking at the use of data and hopefully feeding information back into Design Co". In meeting 2 Simon says "although we're doing this to get good marks, and that's an objective, it's certainly an objective to keep on Design Co's good side, simply because then we get better support from them. Simon also suggests they should make themselves "invaluable" to Design Co with a view to getting a job afterwards. In meeting 3 Toby goes on to say "Design Co are our major stakeholder, we should define the project requirements from Design Co's point of view".

There is no evidence that Design Co ever set down any specific objectives or requirements for the 'new' project. The fourth year project brief originally agreed with Design Co was rejected by the group at the outset of the fifth year, meaning they had no clear brief. The group did acknowledge this... "What Design Co wants is very open", "we're having to develop this process, but haven't been requested any deliverables". The group did not need to limit themselves according to the TSB initiative or any of Design Co's higher level objectives, including that of product 'transferability'. But they chose to limit themselves anyway. Anna had relatively little involvement in the project, and did not indicate she had any particular requirements to be met "I haven't really spoken to you this entire year, since the meeting we had at Design Co, at the beginning (meeting 1), so I don't really know what your project is."

So why did the students align themselves so closely to the 'commercial sponsor' discourse and neglect the 'university' discourse? This finding initially seems confusing, given that the university assesses the project, not the commercial sponsor. A possible reason is that the two discourses are in conflict i.e. 'hard' engineering focused, quantitative, concerned with concrete deliverables, narrow in scope, hands-on level of design vs. value focused, qualitative, concerned with transferable deliverables, broad in scope, high level design. This is the 'central paradox' in the design situation. We speculate here that when faced with this central paradox, the group only partially identified it, and ultimately failed to resolve it. Instead choosing to align their project to the discourse of the 'commercial sponsor', and largely ignore the discourse of the 'university'. This may well be because the groups own discourse, which was value-focused and 'hard' engineering averse, naturally fitted better with that of Design Co.

## 7 CONCLUSIONS

This paper has presented an ethnomethodological case study of a student engineering design team during their final year design project. The results were analysed with reference to a theoretical framework, based on Dorst's model, in which "a 'design problem' is taken as a paradox, made up out of the clash of conflicting discourses". Three key discourses emerged from the data, relating to stakeholder roles and values. That of the 'commercial sponsor', the 'university', and the 'student group'. It is suggested that the 'commercial sponsor' and 'university' discourses were in conflict, forming the 'central paradox' at the heart of the design problem. The data indicates that though the student group partially identified this paradox, they were unable to resolve it, instead choosing to ignore the 'university' discourse, in favour of the 'commercial sponsor' discourse. This may be because their own 'student group' discourse was also partially in conflict with the 'university' discourse, but aligned well with that of the 'commercial sponsor'. The student group went on to significantly underachieve in their design project.

The aim of this research was to explore and describe the complex ways in which design emerges in practice, using Dorst's model of design problems as a theoretical framework. The basic research premise is that in order to improve the way we go about design, we must first better understand how design really happens in the field. The framework has proved a useful and insightful way of considering how design occurs naturally in interactions between people.

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