

**Title: From Data to Knowledge: Tableau dashboards
as boundary objects in the knowledge ecology of a
University**

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Abstract

Information dashboards are increasingly important tools for organisations, helping them exploit data as an asset and make informed decisions. Existing visualisation design research stemming from the cognitive and perception sciences has tended to focus on the cognitive augmenting benefits of information visualizations for the individual in trying to accomplish a task, and make recommendations for design based on perceptual and cognitive principles. However, understanding the use to which information visualisations (in this case dashboards) are put in the management and operations of a large hierarchical bureaucracy that typify the modern organisation responding to complex and dynamic environments, is important for gaining insights that will guide their design, adoption and adaption in these organisations. An ethnographic inspired study was performed at a University who were in the process of adopting Tableau as a management reporting tool, during a period in which there were significant changes to HE environment. The study reports on the evolution of the dashboards, as mediating artefacts, in which the social process of designing takes place. Significantly, allowing communities of knowing to be intimately involved in the building of their own dashboards (through the concept of self-service) allows the dashboards to support the social sense-making roles of “perspective making and perspective taking”. The extent to which the dashboards are able to achieve this is the extent to which they are deemed useful in transforming data into effective actionable knowledge.

Keywords: information visualization design; knowledge creation and transfer; communities of practice;

Attestation

I understand the nature of plagiarism, and I am aware of the University's policy on this.

I certify that this dissertation reports original work by me during my University research.

Signature (signed electronically)

Date 5/04/2016

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Where is the Life we have lost in living?
Where is the wisdom we have lost in knowledge?
Where is the knowledge we have lost in information?

Choruses from “The Rock” in Complete Poems and Plays, 1909-1950 By T. S. Eliot

But when an assignment has been disturbed – when something is unusable for some purpose – then the assignment becomes explicit. . . .

When an assignment to some particular ‘towards-this’ has been thus circumspectively aroused, we catch sight of the ‘towards-this’ itself, and along with it everything connected with the work – the whole ‘workshop’ – as that wherein concern always dwells. The context of equipment is lit up, not as something never seen before, but as a totality constantly sighted beforehand in circumspection. With this totality, however, the world announces itself.

Heidegger *Being and Time* Section 16

1 Introduction

1.1 The Rise of Self-service BI

In a recent research report by Gartner “Predicts 2015: Power Shift in Business Intelligence and Analytics Will Fuel Disruption” published in January 2015, they note amongst a wide range of large companies the balance of power over Management Information systems is shifting from IT to business in the move that end-users are making towards self-service. It is driven by the demand for better access to data and analytics by end users, IT’s inability to satisfy this need adequately and Vendors’ recent developments in easy to use, deployable and mass consumable technologies for basic query, analysis and reporting. It is a trend which is disrupting traditional IT-led business intelligence and analytical models.

Recent developments in information visualisation tools like Tableau have offered the potential to democratise access to data and analytics and have allowed business units to largely circumvent IT. This trend will continue with further developments in self-service data-integration tools for data discovery, “smart” capabilities in data preparation, together with a turn towards the cloud. But Gartner argues that this has come at a price: “as a result, [business units] are disposed to analytical sprawl—an inconsistent or incomplete use of data, capricious development of metrics and formulae, and either too-restrained or unstrained sharing of results”. The lack of governance of self-service driven BI implementations threatens their success and combined with increasing examples of data privacy and security breaches, along with risks of public disclosure inconsistencies, could lead to a zealous swing back to more controlled BI implementations overseen by a somewhat vindicated IT dominated project environment.

Gartner are probably right to anticipate an inevitable counter swing, but what the report emphasises is the developments in the technology necessary for supporting self-service. It leaves open what self-service actually entails. This study hopes, then, to explore what self-service actually means to end-users, the forms that it takes in the work place and to provide an appreciation for the innovative, organisational knowledge creating role that allowing users to build their own BI solutions has.

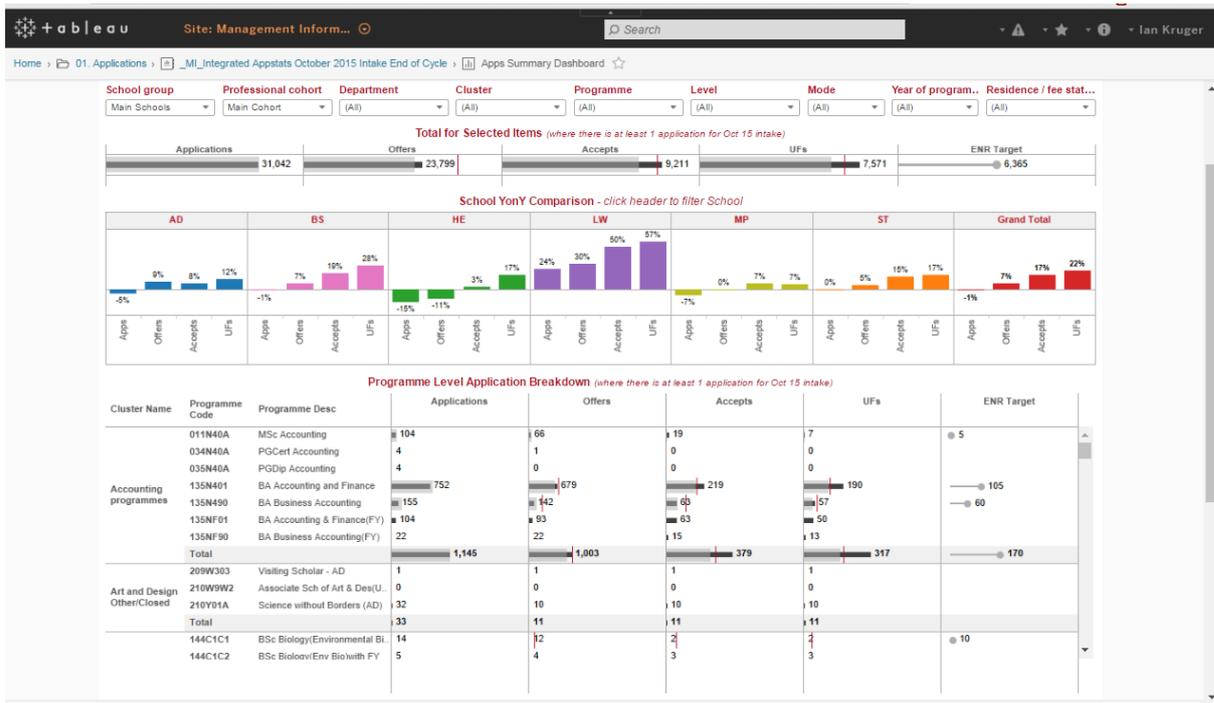


Figure 1: Typical Information Dashboard accessed in a web browser

1.2 Research Site

The study took place April to October 2015 at a London University. The IT department at the University looks after the underlying Oracle based student system (Misis) that houses most student transactional data, and has as its BI role the extraction of data from the transactional system and making it available to the respective departments through an interface (Discover) from which they would typically draw their own data table report, and then if further manipulation and analysis and communication were needed it was done using a spreadsheet application like Excel. There are a range of other specialised applications tailored for and deployed in different departments. There are often other sources of data but these would usually not be integrated and users would have to switch between data sources to try build up a holistic picture of their areas of concern. As is common in other similar organisations, legacy solutions are designed for central control of data and as such present an onerous process to scale and answer inquiries across large numbers of requests (Blue Hill Research 2015). Units using Excel for analysis and reporting create piecemeal, fragmented and siloed data and knowledge across the organisation. There was also a data warehouse project embarked upon by the IT department to cater for some of the reporting requirements via Oracle's Discoverer. This project which was on a 5 year development cycle and was not complete at the time the Planning Unit was setup.

Three years prior to this study the Director of Planning had been appointed under Finance, with a remit to improve management information within the University. It seems that there were several drivers for the setup of the Unit stemming from the dramatically changing HE landscape that needed

to be understood better, a steady decline of the number of students registering and finally the drawing to a close of a previous strategic initiative to consolidate the University into one campus and reduce costs.

The Planning Unit of the University, as described in the staff guide, has a “role to support the university in achieving the vision and objectives set out in the strategic plan for facilitating school, service and institutional planning processes and providing robust information to monitor performance and inform decision making.” The Planning Unit director had to seek alternative development methods to support quick turn around and adaption of reports to match the changes in the market and operating environment of the University. As a result the Unit has been a key driver for making sure that Tableau is the de facto reporting tool and has been central to supporting its adoption by in addition to driving its own projects also providing software, technical and design support and organising an externally run training programme for interested staff members.

P1 the Director of Planning, began by selecting a tool that allowed for a tighter development cycle and after having review several alternatives decided that Tableau was the one tool that had the lowest learning curve and was consistent with encouraging self-service so as not to drain the Unit’s resources. It is important to note that Tableau was not chosen specifically for its visualisation properties, the benefits of which only became apparent afterwards in the course of working with it. There was a two pronged approach to the role out of Tableau at the University, the Unit partnered with departments that were data dependent and helped them become comfortable with using table to develop their own reports; at the same time the Unit was rolling out their own dashboards which were immediately useful to a range of users. There was a rapid growth of requests from a wide range of units for support to get access to and build dashboards, they were encouraged to take control of this process for themselves on the understanding that they remained responsible for their own reporting and know their own data best. However not all were as enthusiastic, and in particular Finance and HR remained circumspect raising concerns around security of data and what the reports should look like. But the IT department, was the most concerned to control access and protect access to the transactional data sitting in the Oracle database. Various work arounds had to be developed as a compromise so that Unit could get access to versions of the data without first having a data warehouse in place. Its wide adoption is an indication that Tableau’s flexibility and functionality has made data work easier for many end-users.

In December 2014 the Planning Unit at Middlesex launched a Tableau Server in which several key dashboards were published and made available through an open portal to a range of staff at different levels and across multiple areas both Administrative and Academic in time for the commencement of the academic cycle related to the admissions process. This area and the critical issue of student numbers were identified earlier as key areas that needed marked improvement in management information.

The University at the time of the study had some 250 users, and about 230 different dashboards used across most department and at various reporting levels within the University. Most of these dashboards were available to most staff through access to the Tableau server portal, although recent concerns regarding misinterpretation and use of the information may result in restrict access to certain dashboards in the future.

This research project takes place in the context of this set up and ends before the launch of a new server capable of supporting the entire university of more than 2000 staff and with a redesigned portal interface to the dashboards.

The Planning Unit at the time of the study was a small unit consisting of the Director of Planning (P1), the Business Intelligence Manager (P2) who left shortly after the commencement of the research and was replaced by P5 at the end of the study, a Planning Manager (P4) whose main focus was planning and who became more involved in designing the dashboards when P2 left, a second Planning Manager (P3) whose main focus was on data acquisition, cleaning and transforming for the dashboards, who had previously been in the IT department and whose familiarity with the university data was a critical asset to the team given the withdrawal of the IT department from direct involvement in the project.

Besides the Planning Unit's own specific projects to do with KPI's and the Admissions related dashboards, it organised training sessions on Tableau for interested staff and provided support and help building dashboards to varying degrees for them.

The dashboards are built in situ with desktop licenses and published to the server portal; as such Tableau is really a platform that allows business users who will use the dashboards to be intimately involved with their design if not actually designing directly themselves and this allows for a different dynamic to emerge from a more traditional process were a skilled designer would elicit from the user a specification, design off-site, test it against specifications, make some adjustments and deploy.

1.3 University Context

In the context of a volatile economic climate and Government reforms of the Higher Education sector UK Universities are increasingly subject to the same challenges as those confronting the private sector and so, in turn, are adopting some of the same management approaches and technologies particularly of the services industry. As Universities develop their strategies with a vision and plans to compete, students become customers and courses are treated as products. Recently, (Deloitte 2015) traced some of the consequences for Universities that the emphasis on increasing student fees as a source of funding for Universities, together with the changes in recruitment restrictions, have had on their practices. These have made it necessary for Universities to take a much more "customer" fo-

cused approach to students. This has ripple effects throughout the value chain of the student experience.

Increasing fees leads to more demanding students in terms of the quality of teaching, learning support given and employability (which in turn means a careful analysis of the employment market and the consequences of these trends for HE). To meet these demands and recruit sufficient numbers of students significant investments are needed; where to invest and ROI then becomes critical to decisions to make. These kinds of questions create a need for managers and operational staff to seek out data and the analytical tools that will help them find answers. An informed decision is better than guess work, a fact where obtainable, is better than an opinion, and to have a coherent argument that makes sense of a broad range of facts, identifies their cause and can determine likely outcomes in good time is more persuasive than intuitions. New knowledge needs to be created. Data is looked upon now as a useful resource to the organisational capability to inform decisions, make plans and monitor performance.

But to translate data into tangible strategic action is a complex challenge, both technical and social. Knowledge-intensive firms are composed of multiple communities with specialised expertise, and are often characterized by lateral rather than hierarchical organizational forms. Their workflows cross many organisational, discipline and community of practice boundaries. Co-ordination amongst stakeholders is essential and yet very difficult. The difficulty is not just technical but epistemic too. The meaning of data and its representations can be very different for IT, for each functional unit and among the various levels of business users. Each adds their own knowledge and artifacts to the organisation. How then do organisations develop successful Management information systems that are cross-disciplinary, multi-function team efforts?

1.4 Scope and Objectives

The reality of self-service analytics and reporting made possible at the University by the mediating and supporting role of the Planning Unit and a user-friendly data visualisation tool, presents us with an opportunity to study how end-users actually design information technology tools to support their local and cross functional communication and co-ordination needs.

The study follows a diverse group of managers and operational staff engaged in the co-design and use of a series of information dashboards to support improved reporting and decision making within the University. The analysis examines the challenges faced by these people in determining how to use the Tableau platform to: assess what data, information and knowledge sources are appropriate; how to source and transform the underlying data; and how to design and use information dashboards—all when existing knowledge of the student journey is distributed across a wide number of people and work-domains.

1.5 Overview of Dissertation

The dissertation is structured on the following basis:

Chapter 2: Vignette 1

Explores the development of a particular dashboard as a key example that justifies a social approach to analyse the design of the dashboards and as a reference from which much analysis and insight will be derived.

Chapter 3: Literature Review.

This chapter explores and works through some the appropriate theory applicable to the research problem. It focuses on one model in particular as a useful tool with which to understand the social dynamics involved and surrounding the design of the dashboards.

Chapter 4 Methodology

This chapter covers the research methodologies used and their justification

Chapter 5: Findings

This chapter applies the model and concepts explored in Chapter 3 to the data to determine whether the model is a useful tool of analysis, whether its key tenants are validated by the data and where the model might be weak and incomplete.

Chapter 6: Discussion

In this chapter we explore some of the implications of the findings for understanding how dashboards are best designed and where further theory needs to be developed

Chapter 7: Conclusions

This chapter summarises the whole argument of the study and its findings, then explores what future research still needs to be done.

2 Vignette 1: Cohort Analysis: Asking new questions

The validity of qualitative research is conveyed in its believability according to Creswell (2012). This believability is rooted in the quality of the descriptions of the setting in order to create confidence in the accuracy of the findings as described in more detail under section 4.5.7 below. It is important therefore to set the scene and give the reader a proper sense of how the Planning Unit typically operated.

In addition Cognitive Task Analysis (Crandall et al. 2006) encompasses a broad range of techniques to collect data about cognitive work, how to analyse it and to use and communicate it effectively. They argue that it is important to understand the knowledge and the reasoning, the organisation and structuring of information and the outcome people are trying to achieve which all underlie competence. A method for collecting data on the cognitive work done within the workplace by is to identify and analyse a critical event.

The following Vignette serves as a capsulizing incident (Crandall et al. 2006) and seeks to capture key features of a typical process by which the dashboards are built and generate insight which is shared and further developed over a short period of time.

25 June Collaborative design

P3 (the primary SQL query writer) is working on preparing the data (with SQL queries on the underlying university student database Misis) for the analysis of cohorts at the university. To secure access to this data has been in itself been a long process of tough not wholly satisfactory discussion with the IT department. He was running queries in a query tool and then looking at the results in a dashboard of some basic graphs connected to the queries. There was an anomaly about the data where there were an almost negligible number of students that had started with a “windy” path and then had got back on a “straight” path which nevertheless undermined the quality of the queries. In order to gain confidence in the data and his queries on that data he had to sort this out first, by manually adjusting those students results so that they would fit the categories that had been established previously. He reasoned (abducted) that the anomaly had arisen at input having perhaps something to do with an outdated entry form. Having sorted this issue out to a satisfactory level (something that could be explained away disregarded as a “frozen accident” (S.L. Star, 1993)) he was sufficiently confident in the data then called P1 (the director of planning) and they went through the results of the dashboard together discussing the results and working through and interacting with filters and tweaking the graphs on the dashboard to better reveal the insight.

When she was confident of her own understanding P1 then invited P6 (Director of Learning, Teaching and Student Experience), whose initiative it was, to come across the open plan office for a quick overview of this latest version and to point out to have a look at what they had found.

The key insight found first by P3 as he was working through the data was the percentage of “windy” students that dropped out was very high compared to those that followed a “normal” path. This insight was of keen interest. It was being explained by P1 pointing directly to the charts. This triggered some questions and some initial hypothesis (was it due to the movement from full time to part time .. perhaps they were winding for a number of different reasons) about why this was the case, and this leads to further requests for a breakdown into subcategories of the windy students. This then became the next requirement for further data sourcing and transformation of data. Further questions came from P6 about aspects of the data none of which could be answered by the present view of the dashboard and requiring further fields or drill down to be allowed. Taking in all that had been discussed P6 wondered if the University’s assessment system was not failing students. This was a question whose answer went beyond the dashboard and its data, as well as Planning and Marketing departments’ span of control. This question was posed as a kind of story and was only possible to ask out aloud (became a legitimate question) after some lower level questions were or could be answered first. It was left as a hypothesis, a tentative theory and the possibility of getting to an answer proof or disproof was enervating.

The dashboard was then passed on to P4 (a Planning Manager in the Planning unit) who was to “beautify” it and add the extra filtering requested. A little later that day there was an interesting discussion between P4 and P1: P4 was asking P1 what a particular label meant and then come up with a more meaningful one that was affirmed by P1. There was a further debate about the use of pie charts as filtering tools and P12 (Head of Admissions Operations & Visa Compliance, a separate but related department), who looked in on the dashboard because of its relevance to his department and made a passing comment that this might not be the best way to do it, it is likely to be misinterpreted. P1 suggested that there could be a long term project to link this data to student logging data.

30 June Sharing across the University

P4 had sent the Cohort dashboard that he had been neatening up, off to a select few Deans and senior staff, and was already getting comments which will lead to some further tweaking. So in this way the insight is distributed throughout the organisation and the comments mean tweaking of the dashboard for the purposes of the user that would help them get their own insight.

1 July User feedback

P4: described the following typical feedback items:

1. There were variables that needed to be separated out from the graphs and did not make sense to include for the purposes and use of certain groups of users like the Deans.

2. The terms used to label items (like variables) was confusing, and there was the specific terms that did not have any intuitive meaning
3. There were repeated requests for a trends analysis based on its usefulness in other dashboards

Not all feedback is equally valuable though and what made feedback most useful was the development of a specific language, a visualisation critical discourse which allowed the designers of the dashboard to know what to adjust. And this seemed particularly developed with P13 (Dean of Engineering Information and Science), perhaps, suggested P4, because of his understanding of the underlying data.

1 September Pair analytics

There was an anomaly detected in the cohort analysis dashboard (students graduating in year 1), this leads to an analysis of the data fields in the original data (which is coming out of the Misis), previously this has led to a series of negotiations (over 4 years) to get Registry to create new categories for foundation years because these were not showing up. P4 made this point that as more people are using the dashboard the more clout they have over Registry to make adjustments to the way that they record and the categories that they use.

There was much discussion about how to eliminate these students and bring it in line with expectations, the dashboard and P3 on excel (derived from the SQL out of Misis which is an oracle application) was involved in finding out. The discussion centred around finding out which column to make or use if it is there already,

7 September Data confusion

In designing the original Cohort analysis dashboard P3 and P2 had been trying to figure out which data dimensions to use to render the graphs meaningful, P3 had created all of these calculated dimensions in SQL that now as he and P4 were working on another aspect of the dashboard both were getting confused as to what the dimensions now meant. They did find a column that was usable in the way that they needed.

2.1 What would serve as an adequate explanation

The emphasis of the activity in the above vignette is on the process of turning the data into something that can be represented visually in the dashboard in order to interrogate the data and make sense of what is happening with student progressions, the key objective is to understand the performance of student cohorts over a number of years. Strategically significant decisions and actions depend on the insight derived from this analysis. And to a large extent it was successful in deepening the University's understanding of its students' journey.

However it is also clear that to look at the principal designer of the dashboard (P3) in isolation of the people and other activities around him is to provide only a partial explanation of how meaning is made out the data and the role that the dashboards are used to support University strategy.

P3's insight was grounded in his long experience at the university and with its data; again this will not be captured by looking at this moment in isolation. Neither is his transformation of the data and designing dashboard the end of the process but rather the beginning. The design process set out by (Munzner, 2014) which first emphasises determining task abstractions and then adding marks, seem peripheral to this part of the process and only become relevant to the second part when handed over to P4 for tidying up the rough dashboard design.

P3 manages only a partial sense of the data, his analysis is incomplete without collaboratively face-to-face discussions around the dashboard, and then later an institutional exercise of due process (Gerson & Star, 1986) of feedback to check, confirm, develop and make more robust if it is to be used across the University.

It seems clear that the design, adaption and adoption of the dashboard are part of a much larger a social process, that stretches across many areas of expertise and attempts to accommodate their perspectives.

An adequate theoretical explanation would need to address and elaborate on these social processes if it is to capture the main drivers of their design. Therefore to address these questions entails enlarging the unit of analysis beyond the analyst and his relationship to the data through the tool, to include the full context of the full organisational activity of making sense of the data. Dashboards are being designed to fulfil social roles around knowledge creation and sharing, rather than for solving a particular problem in isolation.

The theoretical explanation will need to address how the differences of perspective within the planning teams and across organisational boundaries contribute to a deepening of an understanding of the problem without necessarily them achieving consensus on interpretation of the dashboard. Such an explanation would need to remain true to the ease with which organisational boundaries are crossed and the essential role of the developing dashboard in that process. It will need to address the interplay between the analytical and the narrative explanations of the data and how they co-evolve to form detailed and comprehensive understandings of the problem.

3 Literature Review

3.1 Return to the Social

The research in information visualisation under which dashboards would fall has tended to focus on the role that they play in information processing, particularly individual users interacting with a tool in order to accomplish isolated tasks or task clusters Card et al. (1999) Thomas & Cook (2005) and then used to communicate with others Keim et al. (2010). This research has much to say about the cognitive augmenting benefits of visualisations for the individual and would tend to emphasise an analysis of the cognitive and perceptual elements to the task that would guide the design of the dashboards Munzner (2014). In these approaches the role of the social dynamics in the design is less well described and not particularly problematical under the assumption that the perceptual and cognitive abilities of people as described are universally applicable. However many in the field have challenged these assumptions, particularly the relevance of the information processing theory of mind (Winograd & Flores 1986) as an adequate description of how human beings work together in distributed work environments like a University. In contrast (Fields & Wright 2000) and (Carroll 2003) note that there is a parallel trend that takes a more sociological approach to information system design, where there is a realisation that the “design of a computer system needs to be based on a fuller understanding of the socially and culturally structured workplace in which a design system will be deployed.” (Fields & Wright 2000) reference such approaches as including Activity Theory (Engeström 1987) and later (Nardi 1996); and distributed cognition (Hutchins 1996), situated action theory, the work on boundary objects (Star 2010) and communities of practice (Wenger 1998).

It is to this tradition that this study would like to turn, not only because it is somewhat under researched when it comes to the design of information dashboards, but more importantly because there was little evidence in the study that the principles and guides derived from the cognitive and perceptual sciences like (Few 2006), (Tufte 1995) and (Munzner 2014) were actually driving the design of the dashboards in the initial stages where their basic architecture was being laid out. It may be because these principles are already built into the Tableau platform’s affordances thus making them “transparent” and integral to the design of the dashboards but secondary. To be sure the designers in the study had read and became increasingly more skilled in these design principles and were thereby improving the quality of their designs in the process of designing¹. But the main objective was the social process of making sense of the data. The conscious attention to the visual details and the formal descriptions of the tasks the dashboard would support was relegated to a secondary “tightening up”

¹ My assessment was that they were learning the relevance of these principles while designing retrospectively

process (Attfield et al. 2010). Neither was this normative purpose fixed for long—the tasks to which the dashboards were put evolved as more people used them and their requirements were incorporated into its design, again through a social process.

As said in the introduction and described in the context of the study, the Planning Unit and business users of Tableau were not subscribing to the traditional BI development cycles and were to a large extent circumventing traditional IT-led processes in their efforts to martial their own data for self-service analytics in support of activities that often stretched across several work units and levels of management. What is needed then is a theoretical framework that is sensitive to the subtle social dynamic around the design of the dashboards and can afford a deeper understanding of their influence.

3.2 Cognitive repertoires of Perspective Making and Perspective Taking

Out of the wide range of material a particularly significant paper by (Boland & Tenkasi 1995) became an important reference model of knowledge creation and sharing within an organisational context and justifies a more detailed description; its concepts form a framework for the analysis of the data gathered during the field work.

(Boland & Tenkasi 1995) note that the shift from capital and labour intensive organisations has made organisations become predominantly knowledge intensive, that is, they are increasingly dependent on lateral rather than hierarchical knowledge work for innovation in products and services. (Carlile 2002) demonstrates this point when looking at the process of new product development.

(Weick 1995), though, makes a very interesting point about the distinction between layers in management particularly those between strategic thinking of top executives and operational thinking of staff. He notes that the mind-sets are very different: people at the top are thinking strategically and taking calculated risks, people at the operational level are more tactical, local and entrepreneurial and for whom boldness and the exploitation of surprise are crucial. “Projects at the top and bottom differ dramatically, as do readings of the same events” [Pg 27]. Knowledge intensive work is just as important vertically as it is laterally. There is a paradox however.

Knowledge intensive organisations are made up of multiple communities with increasingly specialised knowledge domains and technologies, called **communities of knowing**. These communities of knowing “each deal with a part of the overall organisational problem, interact to create patterns of sense making and behaviour displayed by the organisation as a whole...”, in this way cognition is effectively distributed across the whole organisation. This is not much different from (Simons 2000) argument for the principles of organising for performance by the division of labour and the efficiencies to come from specialisation. However for (Boland & Tenkasi 1995) communities of knowing is a broader concept than work units, like communities of practice (Wenger 1998), they can be sited with-

in divisions, functional areas, product lines, professional specialities, project teams and so on. Employees might find themselves part of several such communities, which overlap in complex and shifting ways.

Drawing from (Kuhn 1970) the notion of a paradigm, they want to emphasise that these communities, by the unique “normal” knowledge work that they do, become “incommensurable” with each other and resistant to change. The point is that each community of knowing develops a common set of habits, customs, priorities and approaches that both produce new insights and enables them to operate internally smoothly, efficiently and effectively, with little concern for how what they know is to be transferred to other communities. They establish over time their own unique interpretative repertoires that remain largely implicit in their activity and separate them epistemically from other communities. In this way there emerge significant enough differences to make translation and interpretation necessary and extra work in communications among them.

The challenge for these organisations is to facilitate both the development of the distinct knowledge within these communities of knowing called **perspective making** and to nurture their ability to take the equally distinct but largely implicit knowledge of other communities into account called **perspective taking**, thus allowing for this knowledge to be shared across epistemic boundaries for organisational knowledge creation. The proper unit of analysis for the creation of knowledge is not the individual in isolation but rather the community of knowing.

PERSPECTIVE MAKING takes place within and constitutes the community of knowing. This kind of knowledge work is the means by which that community deepens its understanding of its own problem domain and strengthens its own practices—it makes a perspective on the world that is entangled with the work that it does and the artefacts that it uses. Relying heavily on (Bruner 1986) & (Bruner 1990) they argue that the knowledge work done in perspective making entails the interweaving of two modes of cognition. Firstly what is called paradigmatic analysis, which is characterised by “rational analysis of the data in a mental problem space and the construction of deductive arguments.” For (Bruner 1986) “The imaginative application of the paradigmatic mode leads to good theory, tight analysis, logical proof, sound argument, and empirical discovery guided by reasoned hypothesis.” A good argument is logical, coherent, consistent and non-contradictory. It is taken as a true that there is an external objective reality or at least directly accessible facts about the world, which present “structural constraints on action and defines what is rational” (Boland & Pondy 1983) and which can be systematically investigated. Paradigmatic thinking then has much in common with the argument for analytics in Davenport & Harris (2007) and the objectives of Thomas & Cook (2005) with their description of what analysts do: “[They] make judgments from evidence and assumptions using reasoning. They seek and process a set of information, ideally from multiple sources; assert and test key assumptions; and build knowledge structures using estimation and inferential techniques to form chains of reasoning that articulate and defend judgments on the issue.” But unlike (Thomas & Cook

2005) whose emphasis on the analytical leaves them without an adequate explanation of how collaboration takes place, Boland & Tenkasi (1995) have the social as part of the description of perspective making.

When anomalies arise in this analysis or in course of normal work, community members can turn to a second form of cognition, that of narrativization. Narrative is a social sense-making process where a story is constructed of the anomaly in order to restore canonicity, "...a narrative explanation works not only because it is logically acceptable, but also because it is lifelike and plausible; it fits the culturally bounds of a form of life." The notion of a form of life is taken from Wittgenstein and means to capture the matter-of-course, taken-for-granted ways of knowing and acting that we engage in normal day-today activities collectively. A good story is one that is consistent with the evidence, offers a plausible causal chain of events and is internally coherent. It brings meaning to experience. Narrative gives the ability to see the formal connections before prove in a formal way is possible.

Narrative (natural) and Paradigmatic (rational-analytic) modes of cognition are two ways of knowing and taking problem solving actions in organisations; they are not just complementary but are interwoven, forming a genuine unity, where "rational-analytical elements of a perspective in a community of knowing are a product of storytelling as much as they are a medium for it." They work together to **complexify** understanding within the community, moving from global undifferentiated naming of phenomena towards a precise explication of constructs, coherent meaning structures and finely developed problem solving procedures in which members develop a "native competence", developing and expertise in the sense that Dreyfus (1992) means and are better able to do domain specific knowledge work. In this way the community develops a mature perspective that produces amongst its members a unique semi-fixed and reliably interpreted knowledge, the large part of which is tacit and embedded in their practice. Their language will become increasingly esoteric and their practice and decisions intuitive, they will possess a common tacit knowledge with deeply buried assumption not immediately accessible to "outsiders" or even to themselves: if asked they would need to reflect. Within a community the existing knowledge is maintained and refined through feedback processes formed by the established decision routines and policies of that community and its embedded interdependencies.

There is a second cognitive duality described as part of perspective making, here members make representations of what is known within the community and reflect on those representations. If paradigmatic and narrative modes are tools used in a problem solving task, representation and reflection is about looking at the adequacy of the tools to the task and the nature of the task itself. The representation enables the community to become aware of and engage with its own paradigmatic and narrative modes of cognition, the context of their knowing (their implicit assumptions, their interpretative conventions, all tacit aspects of their knowing) is thus surfaced and can then be brought into the

representation, as well as the narrative around it, both of which becomes contextually rich and complexly layered. The analysis becomes more precise and the story richer. This process is very similar to what Nonaka & Krogh 2009; Nonaka et al. (2000) call Externalisation in their knowledge creation spiral, namely the conversion of tacit to explicit knowledge, and the representation in this case would be a conceptual knowledge asset supported by dialoguing in a group context.

For Boland & Tenkasi (1995) the representation is a critical device in the attempt to capture “a community's cooperative efforts to reflect upon, interpret and depict an understanding of their situation to themselves”. But they are not that clear about what drives a community to make representations. Others like Lave (1988), Latour (1987) and Card et al. (1999) have addressed this question more directly, and they would suggest that making a representation is much more integral to the process of complexification than Boland & Tenkasi (1995) would want to admit at first. It seems to me that they want to preserve the idea that representation can only come after perspective making has matured sufficiently to be capable of being explicitly reflected upon as of their current understanding. Eppler & Burkhard (2007) and Eppler (2011) are inclined to argue that these knowledge representations are rather knowledge visualizations used specifically to create and share knowledge, and indeed the examples that Boland & Tenkasi (1995) give: cognitive maps and narrative structures, would fit the description of a knowledge visualization¹. But I would want to argue that the distinction between a representation made in the process of complexification (say an information visualisation) and a knowledge representation is not all that critical to their model as the former embodies the way of knowing and is just as capable of being reflected upon in the way that Boland & Tenkasi (1995) require. This has more to do with what is done with the representation as will be made clear in the description of a boundary object. What does need to be preserved though is the maturity of the thinking entailed in perspective making in underpinning perspective taking.

This dual stimulation of making a representation and reflecting on it, is important for the process of perspective making, as a way of strengthening that perspective by layering more and more of the context into the representation. But it also starts the process of breaking the epistemic hold of the community's paradigm: “Making explicit representations of one's knowledge and understandings to exchange with others enables one to better appreciate the distinct ways of knowing that those others will attempt to communicate”. It is in the sharing of the representation that a second order knowledge work is possible.

PERSPECTIVE TAKING means to describe how communities of knowing are able to overcome their incommensurability in order to work together and take advantage of the distinctive knowledge of other communities without diluting the integrity of their own perspective making. Through perspective taking, knowledge is exchanged across communities, evaluated and integrated to build up the knowledge base of the organisation as a whole. The ability to take another's perspective is the basis of all communication and essential for co-ordinated action. Successful perspective taking requires:

“a shift in emphasis, to focus on the individual's ability to make his or her own understanding visible for self-reflection. Once a visible representation of an individual's knowledge is **made available for analysis and communication**, it becomes a boundary object and provides a basis for perspective taking [in those other communities].” Boland & Tenkasi (1995) [own emphasis]

The representation then is something that at first is and remains part of the perspective making process but its real significance for organisational knowledge creation lies in when the representation is shared with other communities' members and it thereby becomes a boundary object.

Boland & Tenkasi (1995) are less clear about the mechanisms entailed in perspective taking, particularly in whether or how the kinds of reflexivity in perspective making and perspective taking are different—there seems to be some conflation here and therefore the distinction between first order (perspective making) and second order (perspective taking) knowledge work is weakened. It may be that one can do second order knowledge work while still in the process of perspective making. Nevertheless, in the examples and design suggestions that Boland & Tenkasi (1995) give, it seems that the representations, the depictions of a community's unique understanding or at least a component part of it, become boundary object when it is shared. It is in this communal status that the representation becomes a catalyst for second order reflection. Reading into their argument and for the purposes again of using it as a lens into the social dynamics that shape the design of the dashboards, we can say that making a representation is a perspective making exercise for the community making the representation, and a perspective taking exercise for another community with which it is shared and it is in encountering another perspective that the reflection induced by sharing a representation from another community becomes second order reflection. This seems like a convoluted argument and fraught with problems as it implies that both communities need to make their own independent representations shared mutually for communication to flow both ways. This scenario does not fit with the general notion of a boundary object which is a common object that is adapted to local use and this is definitely what they mean when they talk about a boundary object.

It seems that what is meant by this second order reflexivity is the sense, amongst community members (perhaps not equally so) that their thinking is from a perspective and this allows for an appreciation that other equally valid perspectives can be and, if one is to co-operate, need to be taken into account in the way a community comes to understand something that is shared. Members acquire a means of talking about the way in which they think by encountering another perspective as another perspective. The alternative is to impose an understanding but this is to violate the nature of co-operation, is political, costly and often short lived.

While the entirety of that other perspective is inaccessible it can be engaged with **hermeneutically**. So as soon as a community shares a representation of their own understanding with someone from another community of knowing, the response can become a “hinge” or leverage point with which to

gain access to what is canonical in the other community, normally inaccessible but very important to being able to take another's perspective.

It is of these leverage points contained in the shared representations that other community members can make an **interpretive reading**, and can engage in a hermeneutical enquiry. The narratives generated in the process of perspective making can also be a source of perspective taking by members of another community by allowing them to read-into the story their own meanings.

There are three conditions necessary for a community to be able to take into account another perspective, the first is the maturity of the perspective that they have made (a native competence or expertise). The second is reflexive representations of the way in which a community makes a perspective and the third is an interpretive competence. Together it would suggest that there is a trajectory of the representations parallel to the developing maturity of perspective making and the community's reflexive skill to surface its assumptions.

But it is difficult for communities to surface and examine their differing interpretative repertoires. Because of this it is not always successful and often devolves to less sophisticated forms of taking the other into account like stereo typing, subject to biases and ultimately breakdown, basically being unable to reconcile their differences.

According to Hislop, (2013) the description of how knowledge is created given by Boland & Tenkasi, (1995) fits in a practice-based approach to knowledge management. Here the knowledge is regarded as embedded in practice, and because different practices develop around some specific division of labour in order to understand and deal with the specific problems associated with a delimited domain of work, within a particular domain no new knowledge is developed only a deeper understanding of the problem domain. Therefore crossing that boundary becomes a central task not only in sharing knowledge but also in generating new knowledge. And boundary objects are critical to making that happen.

3.2.1 Boundary objects and cross community boundary work

The importance of boundary objects for the model of Boland & Tenkasi (1995) cannot be understated, boundary objects operate in perspective making and perspective taking to bind these cognitive repertoires into one seamless flow of cognition and practice. The presence and the quality of boundary objects is a measure of the organisations ability to support lateral knowledge creation and sharing.

The research on socio-technical boundary objects is extensive and all in some way mean to address the observation that when there is a need to work across organisational boundaries, boundary objects emerge to facilitate or frustrate Oswick & Robertson (2009) transfer knowledge and co-ordinate actions without first establishing consensus nor a common understanding of the whole project, or

business process in which each take a role. In this way a boundary object allows the preservation of perspective making while in the process of perspective taking.

Boundary objects were first described by Star & Griesemer (1989) as artefacts, material or conceptual, that emerge organically to act as translation devices between two or more social groups. Later (Bowker & Star 1999) describe them as:

“Boundary objects are those objects that both inhabit several communities of practice and satisfy the informational requirements of each of them. Boundary objects are thus both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use and become strongly structured in individual-site use. These objects may be abstract or concrete. (Star & Griesemer 1989) first noticed the phenomenon in studying a museum, where the specimens of dead birds had very different meanings to amateur bird watchers and professional biologists, but "the same" bird was used by each group to accomplish a different but interdependent task. Such objects have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation. The creation and management of boundary objects is a key process in developing and maintaining coherence across intersecting communities.

(Bowker & Star 1999) make this observation: “Boundary objects arise over time from durable cooperation among communities of practice. They are working arrangements that resolve anomalies of naturalization without imposing a naturalization of categories from one community or from an outside source of standardization.”

It is important to note that the object part of the boundary object gains its materiality pragmatically: from the way in which people act towards and use it, and not from its substantiality per se. And the boundary part of the boundary object is not so much an edge as rather a zone that is neither here nor there, having some of the potential for both or either. (Star 1989) identifies in her work at least four forms that boundary objects can take based on the nature of the activities engaged in and the nature of co-operation, she describes: repositories, maps, ideal types and forms & labels. Each solves particular boundary crossing problems (Star 1993).

As (Ewenstein & Whyte 2009) point out the manifold uses to which the concept has been extended have also stretched its usefulness, and later (Star 2010) partly in acknowledgement of this clarifies the general architecture of boundary objects as having (1) interpretative flexibility; of having emerged out of the (2) information and work requirements of communities, and (3) enabling the dynamic between the ill-structured, vague and common (or communal) use of the object, with the well-structured, specific, tailored and local uses of the object respectively.

While beyond the scope of this study it is worth noting that boundary objects thus defined are by no means the only description of objects; others like (Ewenstein & Whyte 2009), (Nicolini et al.

2012) and indirectly (Eppler 2011) argue for a multiple theoretical approach to capture a richer understanding of the role of objects in heterogeneous and complex organisations. Although they are focused on a boundary object a description of an object of another kind would enrich Boland & Tenkasi's account of the mechanisms of perspective making.

In the (Boland & Tenkasi 1995) account of boundary objects they have a "symbolic adequacy". Using (Star 2010) to unpack what this could mean, it seems that a boundary object supports perspective making in its local use, and perspective taking in its communal use and is the means by which a community of knowing is able to tack back and forth between the two. Perspective taking is boundary work.

3.2.2 Reconfiguration of the knowledge net

Perspective making and perspective taking have implications for organisational knowledge creation and organisational design not necessarily captured in the literature on boundary objects which tend to see these as fairly static enduring objects of translation and co-operation within an established knowledge net. Boland & Tenkasi want to point to the way in which properly enabling perspective making and taking, as they question and revise routines and create new processes and relationships amongst themselves, leads to the transformations within and between communities of knowing. A technology system and an organisational culture that affords better perspective taking and making gives capabilities to the organisation to reorganise practices within and between communities to respond innovatively to the changes in its operating environment.

3.2.3 Design implication of Perspective Making, Perspective Taking and Boundary Objects for information dashboards

If the dynamics of perspective making and perspective taking are fundamental to the way in which organisations are able to develop their understanding of their own domain of operation and to innovate across epistemic boundaries then one would expect that information dashboards as part of the suite of tools that people use in the process of doing this will be shaped by those forces if not deliberately designed to support these processes.

Indeed it is Boland & Tenkasi's (1995) argument that the design of Information Systems needs to take into account how these technologies affect the perspective making and taking capabilities of communities of knowing and thereby mediate the transformation and changing of relationships among communities.

Therefore we would expect that in supporting perspective making there would be an emphasis on the use of the dashboard in supporting paradigmatic analysis, anomalies uncovered would initiate a narrative which would in turn spur further rigorous analysis of data, this interplay would drive complexification of understanding within a community. Within a community of knowing the refine-

ment of the vocabulary, instruments and theories will have an impact on the design of dashboards if they are instrumental in developing that knowledge, the data analytical capabilities of Tableau would suggest that. One would expect that the problems that they mean to address in their analysis of what they take as their own data are particular to the concerns of that community. The vocabulary developed to describe the phenomena and their understanding of what is going on will guide the design and be imbedded in it. The more the members of a community are involved in the design of their own dashboard the more it will be tailored to suit their own purpose of perspective making.

To support the cognitive repertoire of paradigmatic analysis the dashboards might resemble the analytical artifact described by (Thomas & Cook 2005) and have all the benefits ascribed to information visualisation by (Card et al. 1999). The dashboards will become part and parcel of their decision routines and practice. Because the dashboards are visualisations (knowledge crystallisation) they are also per force representing the increasingly complex and unique understanding of that community, something too that they can stand back from and reflect on as an adequate representation of what it is that they know. One would therefore expect that dashboards would go through an iterative development process of increasing precision, coherence and comprehensiveness as it is developed within a community of knowing.

For perspective taking we would expect the emergence of a representation that would support reflexivity. If the dashboard is taken as a representation of that community's way of knowing it would make the unique thought world of a community visible and potentially accessible to others. In this way the dashboard, if shared outside of the community as part of the process of working with these other communities, would begin to act as a boundary object, supporting perspective taking, allowing members of other communities access to what is important, unique and different about the community's understanding, and to reflect on and begin to understand what that community knows.

Members of other communities will look to the dashboard for a "hinge", something that the interpretation of which gives "access to what is canonical about a community and may be difficult to surface otherwise". It will enable and support a communicative competence within a community, changing the quality of the conversations that functional units have between themselves, as well as those that are more vertical, namely, between management and operational staff.

If the dashboards are used to share knowledge across communities then their design will be shaped by those concerns to allow for multiple interpretations, to support the information requirements of the various communities that use it and lastly while ill-structured in common use can be tailored for local use within a community. (Star 2010).

As (Star 1993) points out: "the construction of [boundary] objects is a community phenomenon [by which she means the whole open system of communities of knowing that make up the organisation], requiring at least two sets of actors with different viewpoints." So we would expect that the

development of dashboards as boundary objects will be collaborative and to be the result of input from several communities if it is to function as an effective medium of coordinated work without needing consensus—in other words the unique and necessary perspectives of the communities involved are preserved and do not necessarily present an obstacle to their co-operation.

Where there are dashboards used by more than one community we would expect greater co-operation between them and where there are few or none one would expect breakdown of perspective taking.

Contained in the quote from Heidegger's *Being and Time* given at the start of this thesis, is the keen observation of how the invisible paradigm in which communities practice is revealed in the breakdown of the tools that they use to accomplish tasks. This phenomenon becomes a useful tool for understanding the impact of the social context on the design of dashboards. Breakdown is then an analytical tool for (Neumann & Star 1996) in understanding how infrastructure is built, and (Fields et al. 2003) use usability issues as an indicator of breakdown in communication to reveal how information was translated between two functionally separated groups of people at an airports enabling their collaboration. Similarly we can use usability issues in the use of the dashboards as a proxy for breakdown.

The extent to which information technology tools like Tableau are able to support these two kind of knowledge work will be indicated by the degree to which it is adopted and used. If dashboards play a role in this knowledge work the use of the dashboards would follow the transition between perspective making and perspective taking cognitive repertoires, and we might see distinct phases in design and use.

3.3 A Framework for Analysis

To sensitise the research to the social dynamics driving the design of the dashboards in order to support self-service, the model set out by Boland & Tenkasi (1995) is particularly useful and is sufficient to capture a broad array of features that later research can synthesis.

The process of perspective taking and perspective making and their operations are particularly helpful in a framework in which to detail the social dynamics of knowledge creation within a large highly differentiated and knowledge-intensive organisation like a University.

Referring to **Figure 2 Perspective Making and Perspective Taking** the basic structure of the elements of the model and how they operate in order to support the creation and transference of knowledge within and for the organisation is laid out. It serves as an analytical framework with which to categorise and structure the complex social dynamics entailed in the building and uses of the dashboards at the University by different communities of knowing.

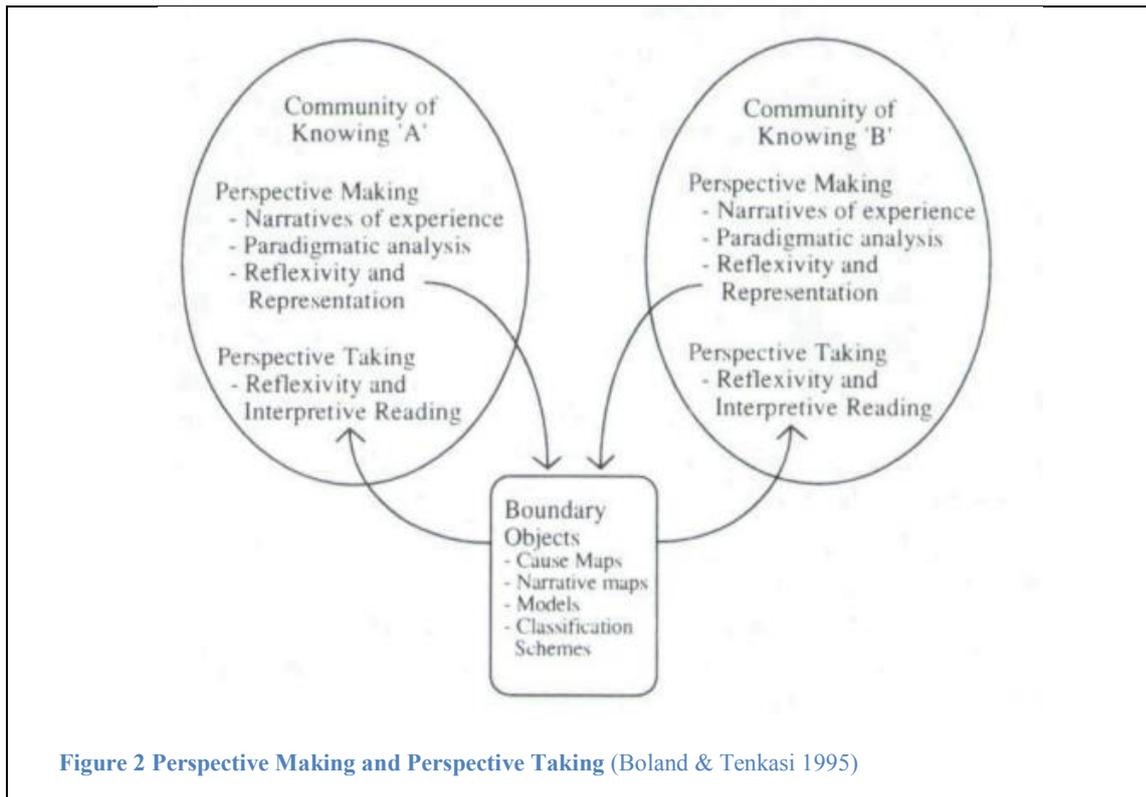


Figure 2 Perspective Making and Perspective Taking (Boland & Tenkasi 1995)

To explicate and extend the model so that it serves better as framework of analysis of the research site, section

4 Methodology

Creswell (2012) describes three broad research designs, underpinned by different worldviews and entailing different methodologies: quantitative, qualitative and mixed methods approaches. The approach taken in this research project was initially and remained dominated by a qualitative approach and design, although because it started to look to more qualitative forms of validation it is closer to a mixed methods approach with a sequential transformation design. This is consistent with an emergent design that characterises qualitative research.

The research was conducted from May until September 2015, and entailed the researcher's placement for no more than two days a week within the Planning Unit's office area of the university. While the researcher was positioned to the rest of the university as a researcher looking at the use of the dashboards at the University, the Planning unit also need certain usability issues explored more deeply and to garner some general feedback from users. It was agreed that since the research entailed interviewing users of the dashboard that the interviews could include questions regarding general usability issues that could be fed back to the Unit as part of its review of the dashboards in leading up to the launch of the new server and dashboard portal later that year.

In line with Creswell's (2012) criteria for why qualitative research will be more effective in this case as a research method:

- The phenomena under study occurred in a natural setting and this was an essential characteristic that we wanted to capture
- There was no a priori established theory or hypothesis; we merely wanted to investigate how people actually made sense of data using self-service tools like Tableau
- The researcher was the primary instrument in data collection, writing a diary, interviewing, making observations and participating in the work of the Planning unit
- The data was primarily descriptive; no attempt was made to quantify observations or interview data. And data was collected from multiple sources: observation, interviews and documents (including the dashboards)
- The focus of the research was on the participants perceptions and experiences and the multiple ways in which they make sense of their work. The focus was on the process of dashboard design and use, on understanding how these things occur
- The meaning and interpretation of the phenomenon was negotiated with participants and emerged from those interactions. In this regard data analysis is inductive, where themes and categories are built from the bottom up. According to Creswell (2012): "The key idea behind qualitative re-

search is to learn about the problem or issue from the participants and to address the research to obtain that information.”

4.1 Strategy of Inquiry

Within a qualitative approach, Creswell (2012) argues that a researcher will need to choose a specific methodology. The research method was broadly ethnographic in style, it had as its object to “learn about the broad cultural-sharing behaviour of individuals and groups” and again “the researcher’s intent is to make sense of (or interpret) the meanings others have about the world” Creswell (2012)

4.2 Role of the researcher

Creswell (2012) recommends that in qualitative research the researcher should be at pains to reflect on the biases, values and personal background that might help the reader understand how these may have shaped the interpretations formed during the study. I have addressed this more directly under **section 4.5 Validity and Reliability**, suffice it to mention here that the University at which the study was conducted, was the same with which the researcher was registered as a student. However the primary site was in another building and in the administrative sections of the University, participants and researcher’s colleagues were unconnected except indirectly for P13. The research question originated out of the researcher’s concern from years of experience in the market research industry that there was a gap between the research done and the actions taken by clients on the one hand. There was always a difficulty in translating the findings into specific actions that a client could take, research was confirmatory or a source of ideas that the client would take into consideration only at a very high level. Furthermore there was always much more in the data that could be more useful but as a researcher one had only the initial commissioned questions as guides, and further questions that evolved could not often be answered because of the strictures posed by the research design.

4.3 Data Sources and Collection Procedures

Field work was conceived as formed by Legitimate Peripheral Participation Lave & Wenger (1991) which describes the process by which novices learn about the practices and gradually become socialized as members of a community. The novice begins with simple low risk tasks that nevertheless contribute to the community’s goals. The researcher was effectively a new member of staff in the Planning Unit and working on the “Tableau Project”, beginning with general user feedback garnered as part of the interviews and ending with the design of dashboards. In this way the researcher was able to become familiar with the tasks, language, tools and organizing principles of the Unit responsible for leading the University in building information dashboards. This research site was specifically chosen for the good opportunity it offered to observe how people actually do go about making sense of data using visualisation tools. The timing of the research in the life of the management information

project was also opportune because there was a history and successes but still evolving. Furthermore there was a good combination of the site being within the administrative functions within the University offered greater generalisability to other similar organisational sites, and it being in an academic environment meant that the purpose and process of research was understood and valued, reducing resistance and suspicion that one might encounter in other more commercial contexts.

4.3.1 Field Diary

A diary was kept throughout the length of the study, documenting observations, thinking, feelings, experiences and perceptions, as well as self-reflections anything that seemed relevant surrounding the as they occurred or soon after. This became a useful resource in tracking the developing thoughts and contextualising the circumstances of the other methods of data collection, analysis and literature reviewing. The field diary became a document incorporated into the research corpus and coded similarly as described in section 4.3 below.

4.3.2 Observations

The researcher spent 2-3 days out of the week for most of the duration of the study at the offices, observing, asking questions and generally participating as a junior team member of the team, so that observations of normal day-to-day practices of the team could be made, these are called unstructured observation by Creswell (2012). More structured observations were also made particularly during Vignette 4 where the researcher was particularly focused on observing and recording (via a voice recorder) the stages and tactics employed as a team brought various pieces of data and attempted to make meaningful dashboards out of them. Observations that seemed particularly significant to the design process of the dashboard like an instance of insight gained from the presentation of an early version of dashboard, were recorded through written descriptions in the form of field notes, audio recordings, and photographs of artefacts either immediately or shortly afterwards. These field notes included making written descriptions of direct observations made as well as inferences drawn. Audio recordings of discussions between individuals including the interviewer and photographs supplement written descriptions.

4.3.3 Interviews

Interviews were facilitated through the planning unit and through the researchers own initiative and meant to cover a broad range of users. A total of 15 people were interviewed, from various departments and levels, some participants were interviewed two or three times. There were regular meetings with P1 regarding the units progress on projects, where findings were discussed and explored. Their relationship to the dashboards varied to include designers and builders of dashboards to end-users. The interviews usually took the form of a general introduction to the purpose of the research, the researcher's role in the planning unit and a request for feedback on their use of current

dashboards. There was a list of fairly general questions that served to initiate the interview and direct it to some extent and then having the interviewee walk-through their most often used dashboards on a laptop, describing what it was saying and the issues that they had encountered while building or using it. Usability specific questions were either covered during the interview or asked specifically at the end. These interviews and the participant's navigation of the dashboards were recorded on the laptop with a screen capturing software. Interview questions were fairly open in the beginning of the research but became more focused around the emerging themes of the analysis of the data towards the end of the study.

See Appendix 1 for list of typical question.

4.3.4 Participation

There emerged an opportunity to actually build a dashboard for the Buildings and Maintenance Unit to display the results of room occupancy data. This project covered the whole development cycle from a requirements analysis with the end-users, data structuring building the dashboard and modifying the design after feedback, ending with a hand-over to the end-users for further development. Notes and recordings were made of discussions with the problem owners in the Unit, feedback and email communications were captured. Version of the evolving dashboards were also saved. Another dashboard was built by the researcher that analysed dashboard user logs. Feedback on its usefulness from P1 was recorded.

4.3.5 Documents

There were several sources of documents that were included and analysed as part of the research. The researcher was given a university email and included in and participated in most of the communications of the planning unit. Those emails relating specifically to communications around the use and feedback on the dashboards were of particular significance to the research as described in section 2 Vignette 1 above. Other documents collected included presentations made by the planning team to executives and other staff, reports relevant to the design of dashboards and relevant memos, as well as written responses to specific questions given to participants.

4.3.6 Audio-visual materials

The primary visual materials captured here were the dashboards (and the data sources on which they depended) themselves, their developmental stages and final production and publishing on the Tableau server were the key artifacts of the research. However, the researcher also took pictures of explanatory diagrams and sketches that were used as part of the initial design phases of dashboards, those explaining the structures of the organisation and of the relationship between data and representations and so

on. The selection of these items came from their relevance to the participants in their development and use of the dashboards, and their use in explaining the meaning of these dashboards to the researcher.

4.3.7 Secondary Quantitative Data

Tableau server has a comprehensive user logging backend recording a range of dashboard usage metrics out of which a dashboard can be built to represent usage patterns see

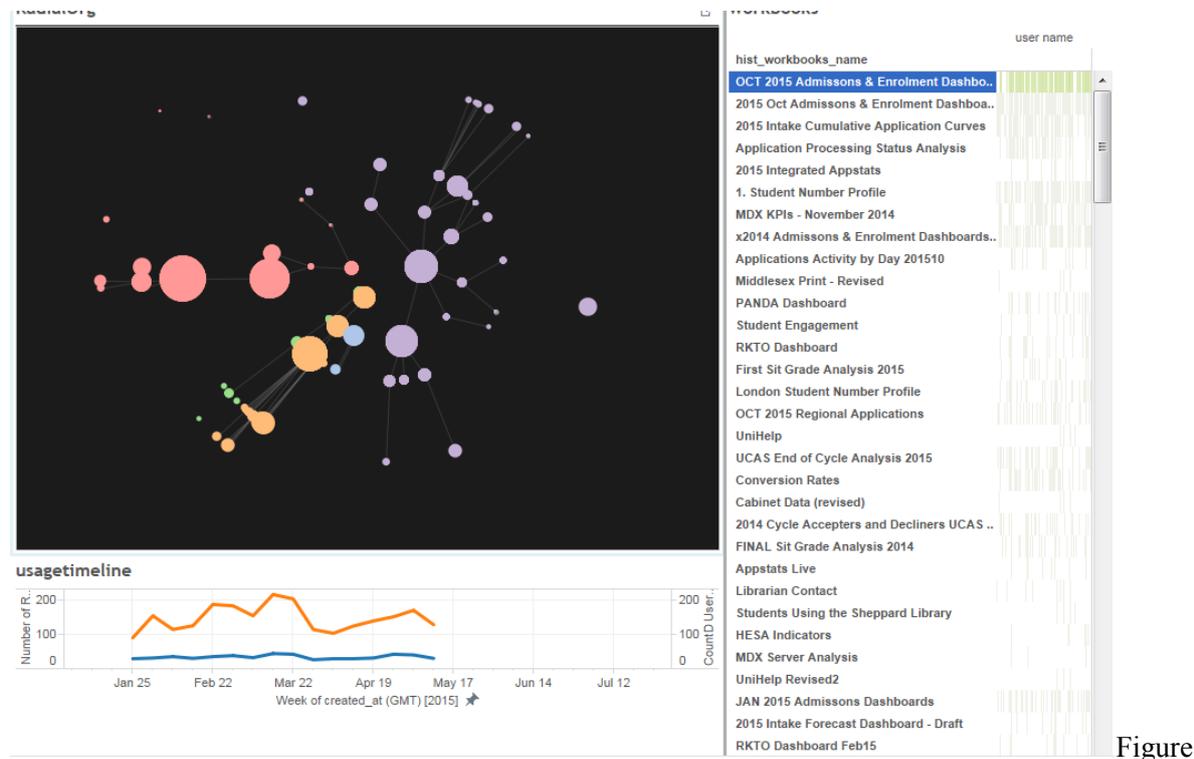


Figure 10

Server Log Dashboard. This data was combined with the formal hierarchy of the University and was thus useful for understanding how dashboards were used across functional boundaries and reporting layers. It was also used to support through triangulation the use of dashboards as boundary objects used across multiple business units.

4.4 Data Analysis Strategies and Interpretation

Creswell (2012) indicate that for qualitative research the meaning of the data emerges inductively and the accuracy of the information analysed is preserved through following a strict analytic procedure: “It involves preparing the data for analysis, conducting different analyses, moving deeper and deeper into understanding the data (some qualitative researchers like to think of this as peeling back the layers of an onion), representing the data, and making an interpretation of the larger meaning of the data.” See Figure 3 Data Analysis in Qualitative Research from Creswell (2012).

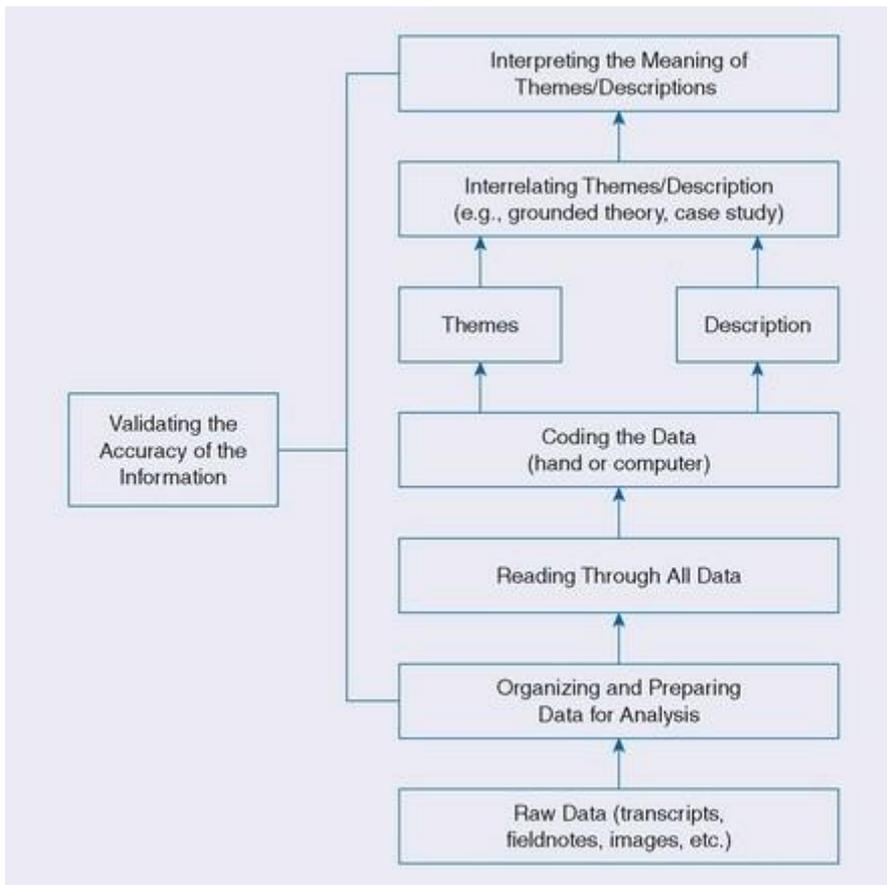


Figure 3 Data Analysis in Qualitative Research from Creswell (2012)

The interview and conversation recordings were transcribed and coded in Nvivo (which also allows one to add other data sources to be brought into and similarly coded thus combining data sources). The process of coding is consistent with Creswell’s (2012) description of grounded theory method, in that there was an initial open coding along the guidelines of Braun & Clarke (2006), followed by an axial coding process where the main emergent themes were located within the theory of Nonaka et al. (2000) and Boland & Tenkasi (1995) which were particularly useful in providing “theoretical sensitivity”, a perspective that helps the researcher see relevant data and abstract significant categories from analysis of the data, thus initiating a third phase of selective coding of all of the interview and document materials. In this way a good portion of the emergent codes were consolidated and then all the material were recode under the themes as described in section 3.2 and 3.3 A Framework for Analysis. In this way evidence for the theoretical framework is grounded in the data, and the data validates key parts of the theory.

Searches then of the corpus on theme codes like “perspective making”, provides a list of excerpts across the corpus where this was spoken about or implied. This allowed for reviewing and clarification of the coding and an enrichment of the description of the themes in a Code Book, as well as establishing the interrelations of themes and their interpretation as described in **section 5.2 Explication and development of the Boland & Tenkasi Model**. These excerpts become the basis for

building vignettes which contextualise the themed excerpts, the richer the excerpt and its context with other themes the more likely it was to be selected as it could be referred to for several themes.

4.5 Validity and Reliability

According to Creswell (2012) within qualitative studies validity is established through the accuracy of the findings from the perspective of the researcher, the participants and the reader of the account. Here trustworthiness, authenticity and credibility of the account of the object of study, are measures of its validity. “Qualitative validity means that the researcher checks for the accuracy of the findings by employing certain procedures, while qualitative reliability indicates that researcher’s approach is consistent across different researchers and different projects.”

Reliability is less important for qualitative research primarily because of the uniqueness of the object of study, nevertheless it can be addressed in the coding phase of the research according to Creswell by ensuring that the interviews and conversations are accurately transcribed; by make sure that there is no drift in the definition of codes. In the case of this research the transcribing and coding tool used links recordings to transcripts and coding so that data, transcripts and coding were constantly compared throughout the analytical process. Nvivo documents this in a way that it is possible for external reviewers to check the data, coding and coding schemes.

Several validity strategies were incorporated into the research and are described below:

4.5.1 Clarification of the biases that the researcher brings

The question that was the focus of this research came from my years as a researcher in the commercial sector and had some frustration with the gap that opened up between the research that we would do and how this translated into actual action (or did not) on behalf of the clients. There was a paradox in that the research needed to be independent of the hopes and intuitions of the executives if it is to contribute new knowledge and give them a proper sense of the state of the market. But that very independence made it difficult to relate to their tacit understanding of their domain and their practice. There was a second concern motivating this research and that was a sense that operational staff are often excluded from the strategic process, except as the providers of management reports, the purview of the executive both structurally and psychologically. This seemed to me to be always a misunderstanding of how strategy gets developed and speaks of the disconnect between executive and operational staff. I was therefore determined to seek out a way in which these chasms could be bridged and to see how people used analytical tools like Tableau to do this specifically. Therefore it is highly likely that on the one hand other means are used to build these bridges, and on the other that these information dashboards are used for purposes other than what I was sensitive to.

4.5.2 Member checking

This strategy entails taking specific descriptions or themes back to participants and determining whether the participants feel that they are accurate. This was perhaps the key method used in the research especially around the themes of perspective making and perspective taking. Typically at some point during the interviews conducted towards the end of the study I would ask would describe the emerging themes and ask if this squared with their own experience in what they had already described to me or if they could find other examples from their experience where this might be demonstrated. I went back to the earlier interviewees to sense-check the emerging findings often several times. Their feedback lead to deeper insights and an enrichment of the themes.

4.5.3 Prolonged time in the field

Here, says Creswell (2012) “ the more experience that a researcher has with participants in their actual setting, the more accurate or valid will be the findings”. I spent almost an entire year with the unit over most of the key events in the academic calendar, both as an observer and as a member of the planning team, this lead in the first instance to a revision of the relevant theory to the object of study and throughout the study a deep understanding of the context and issues participants had to deal with and used the dashboards to support.

4.5.4 Triangulation

Triangulation entails using information from different sources in order to build a coherent justification for themes. “If themes are established based on converging several sources of data or perspectives from participants, then this process can be claimed as adding to the validity of the study” Creswell (2012). This was accomplished by interviewing different people from different units and at different levels of the organisation. Out of this data emerged common themes and established themes could be traced through most if not all interviews and discussions. A second source for triangulation was contained in the researcher’s experience in building an analytical dashboard for a unit as a member of the team. The interactions, design and production of this dashboard was distinguishable from other similar kinds of dashboards only in the particular problem that was being addressed.

Furthermore there was triangulation across qualitative and quantitative (cf 4.3.7 above) where log evidence of the use of dashboards across departments could be seen supporting their use as boundary objects.

4.5.5 Negative or discrepant information

Another strategy to establish validity would be evidence of the use of dashboards that went against the themes. I can offer only a partial discrepant evidence that collectively might contribute some validity in this regard. Firstly, not all of the emerging themes found a place within the frame-

work described in section 3.3 above, and had to remain unexplained within the framework yet seemed quite important, in particular is the materiality of the dashboards in the perspective making process. Not all participants were able to derive value out of the major themes of perspective making and perspective taking, which reduces the concepts' relevance to them and point to the incompleteness of the framework. Secondly there is a very important criticism of the research in that it has a heavy reliance on Boland and Tenkasi's theory (Boland & Tenkasi 1995) and this could lead to a tendency to fit the data to the theory. To some extent this is addressed by the fact that the research remained sensitive to evidence that ran counter to the theory for example that some dashboards were built to be boundary objects before perspective making had been well established and in fact added to a deepening of community members' perspective making. There was also a lack of evidence for most of their recommendations for the social design of technology, which would seem to weaken the usefulness of the theory. These and other discrepancies lead to a re-evaluation of what was important about the theory and an awareness of its limitations.

4.5.6 Peer debriefings

Creswell's recommendation is that the accuracy of the account can be enhanced by "locating a person (a peer debriefer) who reviews and asks questions about the qualitative study so that the account will resonate with other people other than the researcher." My supervisor and colleagues whose expertise lies in this area help considerably.

4.5.7 Rich, thick descriptions

Again from Creswell (2012): Rich and detailed descriptions are a powerful means of transporting the reader to the settings, allowing the reader to share in the experience being described and contributing to the validity of the study. This is the key purpose of the vignettes, the richest and thickest of which were chosen providing a solid framework for the reader to make comparisons with their own experience or similarly described scenes.

5 Findings

Having the theory expand our field of view to include the social context of meaning-making, we can now turn to the data for evidence of these dynamics in the University and the effect these have on the design of the dashboards. It is clear that Tableau as a tool for management reporting has distinct advantages over traditional BI systems based on the normal development cycle, which from the user's perspective break down for two reasons. The first relates to the time taken to deliver results; to develop a data warehouse and then add visualisations takes much longer than the usefulness of the information it delivers, it also has a development cycle that is not in sync with the academic calendar. The ability to react to the changes indicated in the data is a primary reason why one uses it. Secondly and related to the first is that as data becomes available, so users' understanding deepens which in turn change the design specifications.

5.1 Additional Vignettes

As described in 4.4 above the vignettes are selected based on the occurrence of themes as a result of the coding analysis. The vignettes then contextualise the themes; the excerpts containing the richest additional themes became the basis for constructing and presenting the vignettes in the findings. Three additional vignettes are important to add because they allow for me to point out both common themes and subtle but very significant differences. Vignette 1 covers the development of the dashboard from within a community of practice outwards, while Vignette 2 looks at a dashboard or rather a cluster of very similar dashboards that originated at executive level to provide a high level view of the performance of the University but built to service in addition several horizontal communities and levels of organisational hierarchy at once and their adaption of it to local use. Vignette 3 is necessary because it gives some of the finer details of the actual mechanisms typically used in constructing dashboards which is important for understanding the references and quotes relating to the actual design process, and describes the special boundary work that designers typically have to engage in to support a department. The details of Vignette 4 are embedded in the findings but its context is important to set out here.

5.1.1 Vignette 2: The Applications Dashboard

The process by which the Applications dashboard was built is a template for those built to service several functional units around a common concern and for which there was a compelling need for coordination. The driver for the development of the reporting was an executive level requirement to get a deeper understanding of the University's recruitment efforts. P1 had begun with the Excel spreadsheets that were in operation when she started and began to rework them as part of the process of coming to understanding what they meant. There were a plethora of tables in tabs all formatted slight-

ly differently as each person reading from the report had required a different view of the data and without the particular admissions expertise it was very difficult to read. There were two different data sources feeding them, one of which has the target and one of which has the forecasting in it but there wasn't a single perspective that integrated all the data. The biggest problem was not that the reports may have been useful at an operational level, but there was no overview of whether the university was doing well or not, nor was there the ability to compare year on year. The first challenge was then to deliver out of the data a board level report that integrated all the data to provide a high level summary that integrated the two different data sources and provide one definition for cohorts across those two data sources. In this way the executive were able to get a good overview of the situation in recruitment against actual targets and could see the extent of the problem for the first time. Thereafter “we started to change the tactics, and we went from being forecast to be being 26% down to actually recruiting 100 or more students than we had in the previous year.” (P1 during an interview on the history of the development of the dashboard) The new report was having an effect on the quality of its plans.

The third iteration of the report moved from Excel to Tableau and started introducing visualisations but because they were used to them and found it easier to make sense of the data, data-tables had still to be included. Nevertheless the introduction of the visualisation enabled all to see very quickly which course were doing ok and which were not. This changed the nature of the meetings from a line by line review of each course to a focus on those that were not doing well. The connection between the data and the visualisations was becoming more trusted and after this success other reports being built by the Unit took on a more visual quality, timelines and cumulative curves became meaningful and this was true not just for executives but for other departments like marketing. With the visualisation more information could be added without making them too complicated to read, the visualisations integrated in one view tables that users would have had to switch between back and forth trying to build up a picture.

The dashboards revealed that the 2014-2015 cohort had lost a significant number of applicants and a cross-function collaborative effort was established. Using a careful preparation of past and current data, they tried to understand why this was the case and how they might be able to do something about it. In the course of two days of preparing and analysing the data they made some key findings and produced a key document recommending to senior executives courses of action.

By the time of the fourth iteration of the applications dashboard there was hardly any table representations of the data. The individual needs of schools and functional teams were accommodated through filtering. Most of the data was built into the graphs and most importantly progress against targets was clearly visible on a daily basis. The decision makers started using the published dashboard regularly and in meetings: *“[W]hat tends to happen now is that each Dean will have their ipad or laptop open for their own school and they will be looking at their own data and so the conversation has moved on*

from me explaining to everybody where we are to having a conversation about what the tactic needs to be for each of the areas.” {P1E1}² The big difference now is that the dashboard gives a much clearer understanding of what is going on at the University and in each Dean’s area of concern and with this understanding they did know how to act.

Once the dashboard had been developed and published effectively making it an common information space (Bannon 2000) where there were several departments and other individuals through out the University using it, or parts of it, on a daily basis to monitor the numbers of applicants and their status in the process during the student application period stretching from October 2014 to October 2015. They now were able to routinely track changes, do further analysis on exceptions and make tactical adjustments. P13 said that the dashboard was “*crucial, prior to this we had virtually nothing, we didn't have anything that you could look at routinely which meant that you could never track changes*”. {P13E1}

The applications dashboard enabled conversations not just vertically across horizontally contingent units as well that would monitor the progress of the applications process, make tactical decision and arrange of other purposes, even just to get a sense of what was happening across the university.

Two other version of the Application dashboard emerged to get slightly different views, and the duplications were consolidated in an integrated dashboard that was published with the launch of new server.

The University had one of the highest increases in intake over that year, clearly a competitive advantage that they sought to protect by in part a decision by the senior executives to limit internal access to the dashboard and further iterations, to those that had a direct role to play in the applications process. Other peoples’ access had to go through a rigorous process of justification mediated mostly by the Unit.

5.1.2 Vignette 3: Development of the Occupancy Dashboard

Estates at the University has several projects to improve utilization, including the use of sensors under desk and handheld notification systems for maintenance staff. They were getting more demands by senior management to increase utilization, which entailed better reporting and a deeper analysis of the available data so there was a need to become more proficient in Tableau, P8 (Systems Administrative Officer for Estates) was attending Tableau training. One such initiative involved an

² Notation of excerpts: P1 refers to Person 1 E1 refers to the first excerpt from transcribed interview materials. This notation is used so that quotes can be referred to in different contexts of the discussion.

annually run exercise to assess the level of occupancy of teaching rooms done by getting the University's security personal to systematically do a headcount in classrooms, labs, lecture theatres etc. over a period of two weeks. This data had been manually matched to the occupancy numbers Timetabling had planned for, which in turn was derived from faculties estimating numbers of students for particular courses. While this exercise was done for compliance requirements there was a deep concern at the University expressed by lecturers and Facilities that there was an underutilisation of rooms. The researcher became the designer for the development of this occupancy dashboard as a resource provided by the Planning Unit to the department. There had been a dashboard built already by P2 based on a discussion that he had had with P8 but this had not been used in the end by P7 her manager because it did not support his the analytical needs adequately. Over the course of several weeks the researcher had a couple of meetings with P7 and P8 to assess what P7 (Systems & Space Planning Manager, Estates) was hoping to use the dashboard for and what it needed to show. P2's dashboard became the starting point for what still needed to be done. Initially the difficulty for the researcher was determining what the data from the two sources each represented, how it was gathered and its structure, as well as the way in which the key performance indicators of occupancy had to be calculated. The two data sources had to be formatted and brought into Tableau and then connected through "blending" so that expected occupancy could be matched to actual occupancy for each room over the period and metric for occupancy performance calculated and represented graphically; this metric is an indicator of the effectiveness of the department. Different graphs were created in the Tableau desk version sheets giving different perspectives on the data, and these were then combined into one dashboards with selective filtering (see Figure 4 Occupancy Dashboard). In this way P7 and P8 could interrogate the data to identify and drill down into rooms that were systematically under or over occupied, which amongst other indicators would give a course of action for the department. All of the functionality described is built into Tableau.

A review by P7 of the first iteration of the researchers' dashboard did not yield expected patterns and a key metric had to be recalculated calculated to reflect what P7 knew from previous years of experience and him working with the raw data. For the researcher the exercise became a way of entering into a the domain of facilities management and revealed its interdependencies with other units. Building the dashboard has an impact on the way the data was to be collected in the next exercise and also reveal changes in the categorisations and allocation coming from Timetabling that had not been communicated officially. P7s wants the dashboard to be shared with several key people vertically and horizontally and was keen that it allow them to interrogate the data for themselves Who he wanted to give access to reveals his picture of how his functional unit is connected to the wider organisation. What the dashboard shows has implications for these other units in particular Timetabling and the Schools and their programmes.

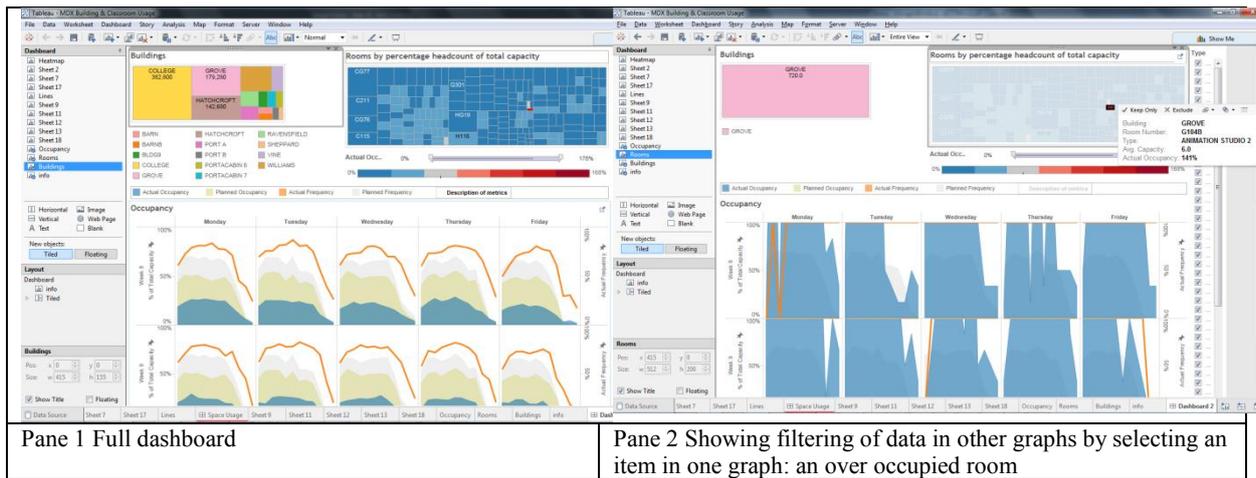


Figure 4 Occupancy Dashboard

5.1.3 Vignette 4 Bring your own data

P9 (Head of Student Recruitment Marketing) was in the process of driving a data analytics strategy within her function by getting each of the 5 units she oversaw to build their own dashboards out of their own data, that she would eventually bring together to form a complete picture of her whole function. She had found that data analytical skills were not evenly spread across her team and had to devise several approaches depending on the circumstances and analytical ability. One such strategy was to set up a day away from work for one of her teams to bring the data that they normally worked with and facilitate the building of some key graphs and a dashboards, after two staff had been through a Tableau training course. The researcher participated as an observer of this session.

5.2 Explication and development of the Boland & Tenkasi Model

To explicate and extend the model so that it serves better as framework of analysis of the data, a graphic was developed and is described below. The major limitation to their model is apparent in the difficulty the reader has in relating the recommendations they make for an idealised organisational structure that supports perspective taking and perspective making, to the reality that he or she is presented with in their own organisation. Starting from the other end by looking at how a tool like information dashboards are actually used and relating this to the model allows us to articulate the model in a much more practical way and make it conceptually more robust.

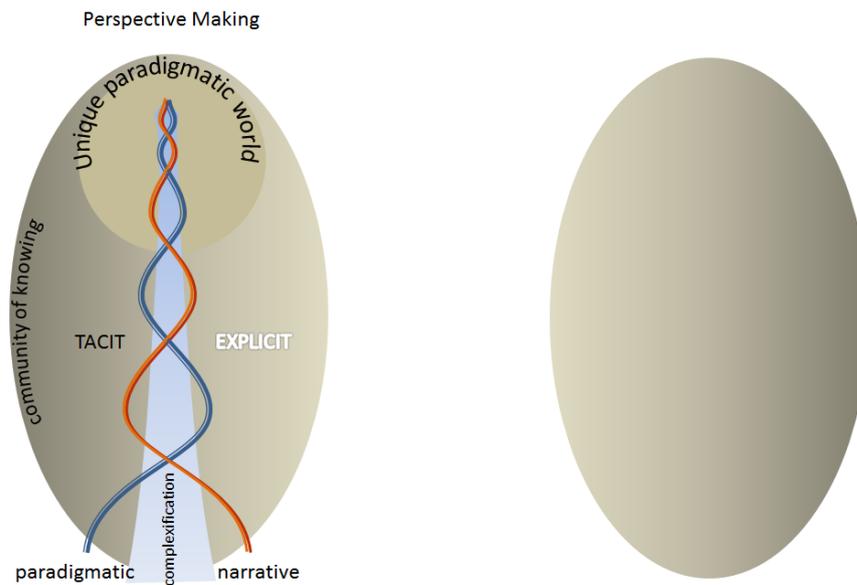


Figure 5 Community of Knowing & Perspective Making

Referring to Figure 5 Community of Knowing, the making a perspective is underpinned by the process of complexification is driven by the caduceus-like interaction of the two modes of cognition: paradigmatic and narrative. At the beginning of the process (at the bottom of the “community of knowing” ellipse narrative and data can be vague and far apart but as they co-evolve they become more tightly integrated, focused and detailed to form a unique coherent paradigmatic world or worldview for that community. It is important to note that there is both a tacit and an explicit form of the knowledge contained within a community and the paradigmatic and narrative modes convert tacit to explicit (as in Nonaka’s knowledge creation model at the internalisation and externalisation phases).

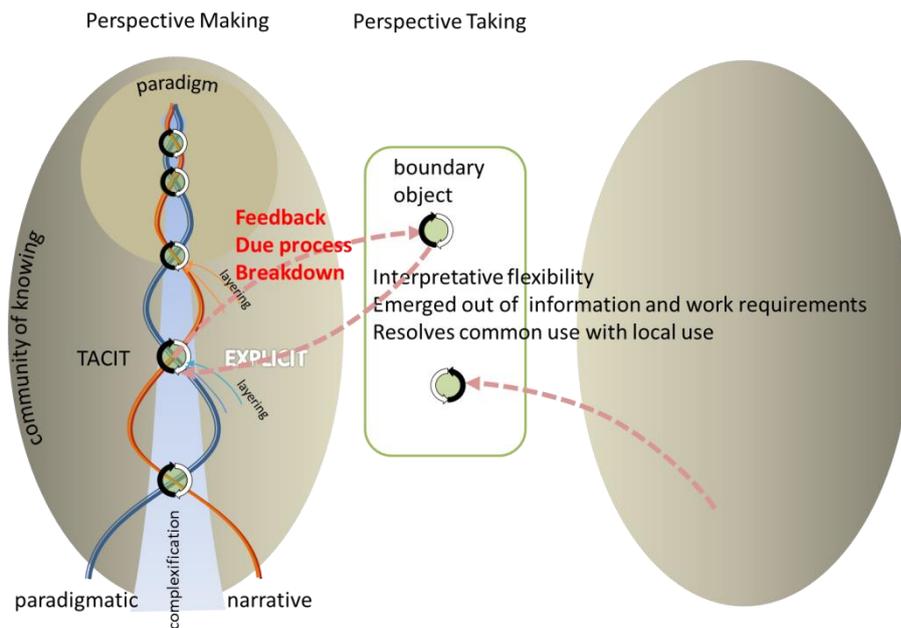


Figure 6 Perspective Taking & Boundary Object

Referring to Figure 6 Perspective Taking & Boundary Object, the design of the dashboard as a part of the process of perspective making both evolves and concretises the increasingly sophisticated understanding of perspective making. It sits at the intersection of these two modes of cognition as a mediating artefact, and embodies the knowledge thus created. It is use initially as an analytical instrument and then at a certain point of maturity, operationally if it is based on transactional data. In the metaphor of the caduceus the dashboard is the staff around which the narrative and paradigmatic modes of cognition are able to wrap themselves: the result of an analytical exercise needs to be interpreted by the elaboration of a story, a story about what happened grounded in the data evokes further more precise questions that need to be tested against the data analytically. In this way the layering of more data and richer elements of the narrative become woven into the dashboard.

At some point of articulation the dashboard is shared with other (connected) communities of knowing (both vertically and horizontally) and thus becomes a **boundary object** enabling perspective taking or the sharing of knowledge, enabling co-ordination of work and collaboration across boundaries. The dashboard's design is shaped by boundary work of feedback, due process and instances of recovery from breakdown (in communication and/or workflow). At this point there are often two version of the dashboard, one used operationally and granular and another used as a communication tool--often at a higher level of representation. This can be within one dashboard configured with different views or it can be two separate dashboards. There are several strategies to solving the requirements of a boundary object depending on the nature of the information and co-ordination required.

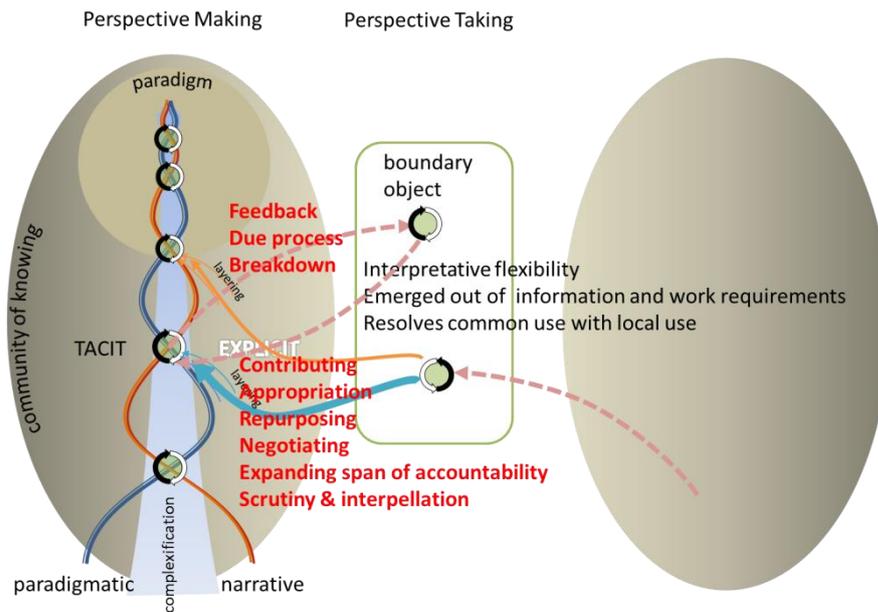


Figure 7 Boundary Infrastructure

Figure 7 Boundary Infrastructure, demonstrates that when we have several communities creating and sharing dashboards, collectively they start to operate as a boundary infrastructure. Here knowledge developed in one community becomes used not only to get sight of what is happening across the organisation without the expertise to understand another domain, but also to enrich the perspective making process through appropriation, repurposing, negotiating etc. of relevant knowledge.

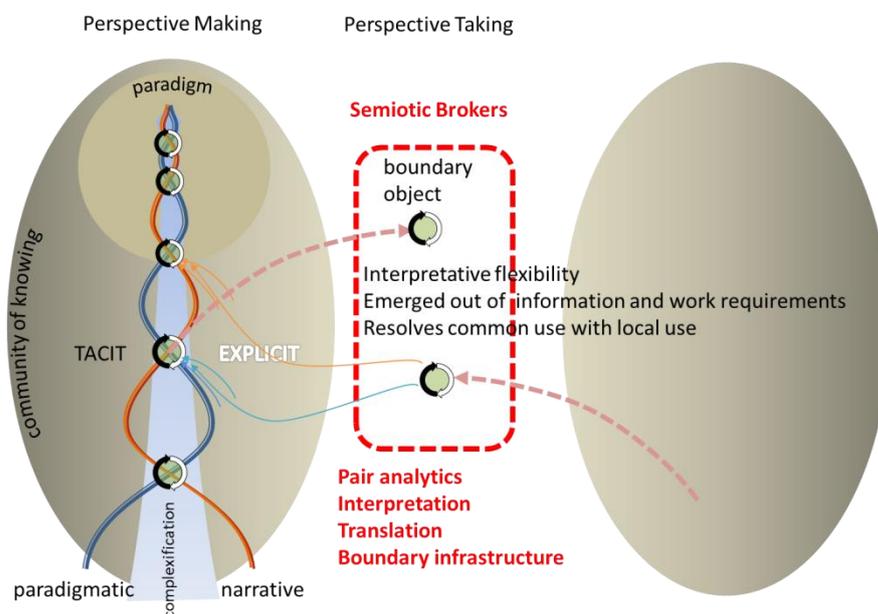


Figure 8 Semiotic Brokers

Semiotic Brokers (Figure 8 Semiotic Brokers) are those who in Boland & Tenkasi’s description of an idealised organisation are people “who play important liaison roles between strong communities of knowing use their newly developed skills ... to help facilitate the perspective-taking process.” Figure

8 Semiotic Brokers represents the mediating role of these workers and gives some sense of their role as interpreters and translators, as supporters of the analytical process of weaving data generated in one domain (typically the data maintained in transactional systems by IT) together with narratives in another domain to build dashboards that operate as boundary objects.

5.3 Communities of Knowing

The finding of this study is that there are several organisational group configurations that will satisfy the definition of a community of knowing, there is most obviously the functional unit as defined formally by the organogram both horizontally, and vertically—the executive form their own community of knowing as executives, while at the same time representing their divisions. There are issue specific teams or interest groups that emerge like that group of managers focused on the applications process, which cut across these functional boundaries. Another such community is formed out of those individuals peppered throughout the University that are responsible for the design of the dashboards. Staff might be in several communities at the same time. For example, P1 is both in the Planning Unit and in the “Tableau Project” of which there was initially considerable overlap but later started to diverge in concerns when the Planning Unit became responsible for driving the University’s strategy refresh. For this study what is important is that the community forms in the process of perspective making and can be indicated by its efforts to establish a well-developed paradigmatic analytic methodology and a rich coherent narrative to provide a robust meaning structure of its problem. Vignette 2 describes the collaborative formation of that community of knowing that overlaps several interrelated units associated with the student recruitment process including Admissions Operations, Marketing and Faculty.

5.4 Perspective Making

Where ever there was a group of people working on a common problem, doing specific and unique work, they are also involved in perspective making. In Vignette 1 the development of the Cohort dashboard was for the Learning, Teaching and Student Experience department. The insight gained by the analysis and the narrative of the “windy” student path deepen the department’s understanding of its area of concern and gives guidance to its practice.

5.4.1 Complexification

Complexification is the process by which narrative and analytic cognitive repertoires stimulate each other in the process of deepening a community’s understanding of its problem domain. At the University this played out in the way in which the dashboards were used as analytical tools (paradig-

matic analysis) the results of which if not the very process became the source of a particular dialogue (narrative) about what this meant and what they needed to do tactically or operationally.

The evolution of the **Applications** dashboard in Vignette 2 went through a series of iterations over two years moving gradually away from an Excel spreadsheet with numerous tabs of data tables to rich but easy to grasp visualisations that did a lot of the analytical work that the executives had to do in their own heads to understand what is going on. With each iteration of the dashboard the nature of the conversation at executive meetings evolved too, from a concentration on what the numbers meant, to a focus on what the University needed to do. If the goal of perspective making is a precise, coherent understanding of the dynamics of the problem domain around which there is consensus then we can say that this has been achieved for the moment amongst members of applications process community. Their tactical adjustments had a significant impact on the numbers of students recruited which validates their perspective.

Another example comes from P14 (Head of Library and Learner Development) who said that initially they had no clear idea what it is that they needed from the dashboards, the work that P15 who had been given the responsibility of building the dashboards had been doing was really part of the discovery phase, and had helped clarify what it is that the Library needed to get a handle on, they were now in a position to give more systematic feedback to P15 on her initial designs because they can now shape the way in which the dashboards need to go.

“What we are doing with [the dashboards] in LSS is something that we have not been very good at, and that is actually recording our activities and use them to make decision about the services that we provide. And what is great about Tableau is that we have it all in one place and it is easy to use and read. The visual side of it is lovely. Let's go into an example for a little more detail. I have my team of librarians and we have been keeping stats on the work that they have been doing in terms of teaching session for students for years and years but we have been doing it on spreadsheets so all you see is numbers on a bar chart or whatever. Whereas what is really nice with this[dashboard] is that you can look very simply and easily and say over the past 5 years the amount of support that we have done has grown exponentially” {P14E1}

5.4.2 Paradigmatic analysis

Information Communication Technologies are according to Boland & Tenkasi most suited to supporting the paradigmatic information processing form of cognition. The Tableau platform therefore is better suited to support members of a community in structuring their quantitative data and analysing it systematically, to derive empirically grounded insights, test hypothesis by interacting with the data, finding suitable representations and developing sound theories of what is going on—all characteristic of the paradigmatic mode of cognition.

After trying to get a handle on what the data is saying, a key design goal of the dashboards was to use it to support a well-constructed and logical argument for a course of action, where decision are based on facts presented or representable in the graphs. Cleaning, transforming and blending data from different sources was an exercise in paradigmatic analysis as illustrated in Vignette 1 by P3's work to tighten up the categories of student progression paths and understand how the anomalies could arise. The importance of this knowledge work in establishing a set of data on which there was consensus was underscored by P1 when she pointed out that the dashboards helped in meetings (of the executives) because the underlying data did not need to be explained but now supported more fully the tactical decisions that needed to be made.

P13 (a Dean of School) made the same point; for him, as part of the executive community, dashboards helped him *"track the stuff and if I find an anomaly I can immediately contact P1 and say: 'what has happened here, why so these numbers are ... should never go down'."* {P13E2}

In this way, P13 is demonstrating the role that his interaction with the applications dashboard in particular is used to maintain and refine the executive community's knowing. Routines and policies have been built into the dashboards.

P13 (Dean of the School of Engineering Information Technology & Science) was also using some of the dashboards forensically to bring out some underlying trends which he can use as evidence to back up an argument for more resources for his own department: *"...so when people say to me 'But don't forget that the University's numbers are going down', I can say 'hang on a moment my numbers have gone up by 25% in the last 5 years', and I have the data now to show that."* {P13E3}

P9 (Head of Student Recruitment Marketing) successfully built a business case for a brand perception survey based on arguments derived from a dashboard-mediated analysis of recruitment marketing data that systematically eliminated other operational causes of the drop in application numbers. As described in Vignette 4, P9 was also engaged in a lengthy process of getting her staff of the various units that she oversaw to build their own dashboards so that dashboards could be brought together to provide a comprehensive picture of all the touchpoints along the customer journey of a prospective undergraduate student. Her difficulty was in cultivating a paradigmatic mode of thinking in her staff, and the ability to "identify the analytical potential in the data" was not evenly distributed across her teams.

"I have marketers in my team and there is a tendency for them to be creative or analytical and you can't be both, or there's not many [that are]. And the other challenge that I have is that there are a number of touch points that we look at in isolation. Well I would want to connect them and see the relationship between them, between the impact of those different touch points, and I don't have anybody in my team who can actually understand how to do such a complex thing. So that's why I said: 'bring your own individual elements and I will be connecting them'." {P9E1}

This issue of having a skill in paradigmatic mode of cognition is brought out in Vignette 2 where it was described how a collaborative team was set up in order understand where in the process and why the University lost a large number of applicants, and this entailed a thorough preparation of the data and a systematic analysis of this data using Tableau and Excel. Their objective was to determine which groups of students showed the biggest drop and then analysing each part of the applications process to determine at which points there were significant drop-offs as a way of identifying bottlenecks. At the end of the analysis there was an action plan to say what was needed to be done to resolve it. It was a group of people who were more capable in doing an analysis of this kind and who had a vested interest in making sure that the same thing did not happen the following year. The most important things were a good data set, tools that could support the analysis and a group of people coming together around a common interest.

5.4.2.1 Sense-checking data through triangulation

A crucial exercise in building confidence in the data on which the visualisation was to be built depended on comparing the results generated from other sources like directly from the Oracle database system's reporting tool or from what was already known.

5.4.3 Narrative

The interweaving and dual stimulation of paradigmatic and narrative modes of cognition described by (Boland & Tenkasi 1995) is clearly apparent in the way in which people work with the dashboards, particularly when they were in the process of making sense of data, either in dealing with an anomaly that has arisen in the course of using the dashboard (see {P13E2} above where P13 draw upon social resources through a story) or in the beginning of the process of designing the dashboards and everything is still very much exploratory.

For example in Vignette 1 the Cohort dashboard, as P3 was working through the list of students that did not fit the categories he had previously established he was as much talking to the researcher as to himself about what this means and how he was going to deal with it and whether this was an justifiable approach. This lead to a tweaking of the SQL query to re-categorise the confounding variables and provide a more coherent account of the data.

Later in the same vignette he talked through what the graphs meant with P1, teasing out the story it told about the student journey over the years of study; and this same story was repeated when Katie was taken through the dashboard. She built on this story with her question about whether the University's assessment systems are designed appropriately for these students, it was not a question that she could ask until the facts had been laid bare. This story is further elaborated when P1 discusses the dashboards with the other schools in "*various meetings where people are identifying that we have a*

retention problem and are starting to question whether we have the right KPI for student retention/progression”. {P1E2}

In Vignette 1 there was an evolving vocabulary as to what to call these students who do not follow standard academic progressions, “windy paths” was a powerful metaphor because it prompted the need to determine finer distinctions in paths and to identify higher risk groups and paths. The evolving narrative has significance because it was an interesting, plausible and believable account of what it is like to be a student progressing through the University learning system. And it sets the context in which further paradigmatic-analytical work (more data transforming, integration and visual analytics of results) can be done to establish the truth of these possibilities.

P13 in demonstrating his use of a particular dashboard, manipulates filters in order to create a key anchor around which to build a compelling story *“if I take out the January starts and look at the main stream you can see that [the trend] is even more strong, so now I have an interesting story to tell.... There is an interesting story here, my numbers are going up quite consistently here and everyone else’s is going down so I am actually bucking the trend.”* {P13E4} Here the narrative makes sense of the data, and the data lends weight to the narrative. More analysis will either strengthen the story or weaken it.

Narration was a key device in how each interviewee took the researcher through what their unit did and how this was revealed in the way they explained the meaning of the numbers and graphs of the dashboard that they used. The story of its development, the role of the unit in the University, what the blip in the curve of a graph meant and so on, all these helped the researcher gain a deep understanding of how sense was made of the data using the dashboard.

P9 explains a cumulative curve graph (Figure 9. Cumulative Curve of Acceptances of Offers) within a dashboard that she used, that represented the numbers of students accepting offers over the course of the academic year compared to the previous two years: *“This is very interesting to see what is happening here and here, you see there is a change in behaviour that actually started here [circled in red in the figure] when we automated offers—we started to send automated offer letters which allow students to accept an offer much easier. You can see that from that moment on [the curve differs from previous years] because it is related to offers been given quicker as well but in the past an offer would have been sent to an applicant but it was sent to an applicant later in the process of accepting an offer.... Now an offer is emailed to the student on the same day and they can just click a button to respond. So there is an instant correlation. Whereas in the past there wasn't such a strong correlation”* {P9E2}

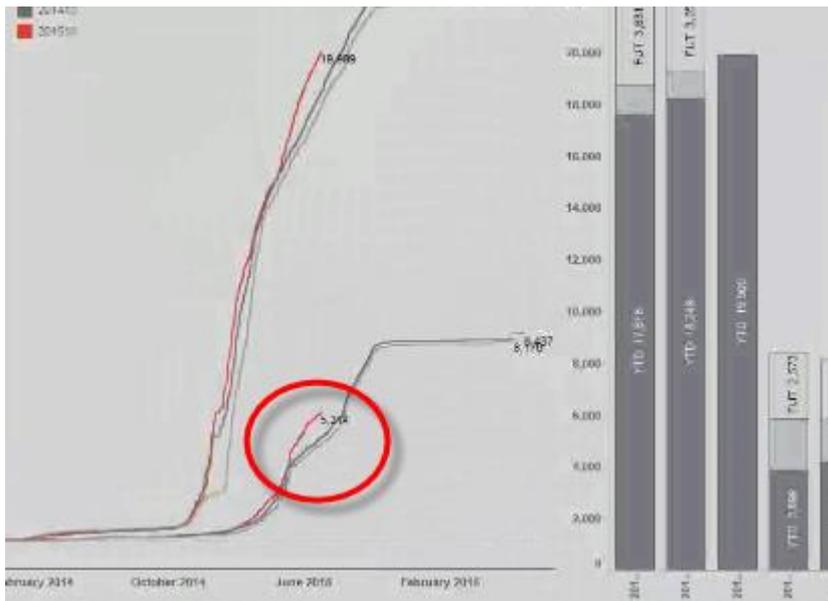


Figure 9. Cumulative Curve of Acceptances of Offers

Narrative has another important role and that is in the way it is able to surface the underlying assumptions behind the paradigmatic analysis

5.4.4 Representation

In the model that (Boland & Tenkasi 1995) describe, representation has two roles the first is that it allows members of a community to surface and reflect on their own way of knowing which is otherwise largely tacit and embedded in their practice, and in this way members become more aware of the way in which they work and layer this understanding into their representation. Secondly it gives something material in the sense that (Star 2010) means to share across epistemic boundaries thus enabling perspective taking. It is the findings of this study that the dashboards play both of these roles.

5.4.4.1 Reflection on the representation

Exploring the first use of representations: while the dashboards are not a deliberate effort to represent the community’s way of knowing such as cognitive map they still serve to surface and evoke reflectiveness on what that community knows and do so in two ways: in the process of co-designing the dashboards and secondly in the way it reveals contradictions and anomalies in the knowledge and practice of a community that result in an enquiry.

Because the dashboards are intimately involved in the process of perspective making, it does become a representation of the evolving nature of that understanding of the community. The evolution of the dashboards is an evolution of their thinking. So sourcing and adding more data to the dashboards, blending data sources and adding filtering that allows users to connect different data representations in the dashboard requires that community members step back from their normal work and reflect on the ways in which they understand and carry out their work, assessing its efficiency and effectiveness.

And this would often be supported by knowledge representations of the kind Boland & Tenkasi describe, sketched hastily to solve a particular problem or as a conscription device (Henderson 1991).

The second way in which the dashboards evoke reflection is captured in the interview excerpt: “*track the stuff and if I find an anomaly I can immediately contact P1 and say: ‘what has happened here, why so these numbers are ... should never go down’.*” {P13E2}

Here P13 poses the possibility of him finding something that does not make sense given what the community knows—an anomaly—and initiates a process of trying to understanding the context in which this could have occurred. Whatever the outcome of this enquiry may be (perhaps a change in practice or a deeper understanding of the recruitment process, or a modification of the dashboard) the point is that addressing the anomaly entails a reflection that would not have been possible without something like the dashboard.

Stepping back and reflecting on a community’s knowing and practice is a difficult process as the following excerpt demonstrates:

P12: We are all going on Tableau training so that we can write our own reports

Interviewer: how's that going? Do you think that that is a good idea?

P12: I think it's a brilliant idea if I just had a few quiet hours in my busy day to get a few things done in terms of Tableauing³. I just need a quiet day. I will get loads more things that I run regularly, up on Tableau...

Interviewer: assuming that you have some time what would be the advantage of you doing your own dashboards above instructing someone else to do it?

P12: because in that way I could make it exactly what I wanted... It's entirely selfish so that I can display the data in the way that I want it, where as I had to live with some of the irritants... So for example this dashboard here I only look at the left side I only look at this information here I never look at this information here because I just don't find that as useful but it does have a use to questions that are asked by the executive, they like to know overall where we are with things. Whereas I'm concentrating on these boxes which are actually related to my team and the number of incoming applications and the total outstanding actions that we have. Because of the UCAS deadline, we got 15,000 applications in a week so it takes quite a while to move those through the process ... {P12E1}

5.4.4.2 Layering

The concept of layering is important for explaining the iterative development of the dashboards observed. There was a definite trend across all the dashboards and captured in the vignettes, where the dashboards would go through several iterations in which more information was packed into the visualisations, different data sources are being brought into one representation and different

³ This conversion of the noun into a verb indicates the close association that end-users have between the tool and the task

representations being brought together and related visually, if not physically through filtering (Panel 2 Figure 4 Occupancy Dashboard), in one dashboard as described in Vignette 3

P14's experience is similar when building a dashboard specifically for his unit

"... And I have been trying to do this sort of thing for years with Misis and it has been so protracted and I have needed lots of other people to do for me...where as on Tableau I have this data at my fingertips." {P14E1}

It seems from the research that there are two ways in which the dashboards become increasingly more dense and comprehensive, although there maybe dashboards not explored in the research that show a different trend. The first mechanism is rooted in perspective taking and forms part of the process of complexification involves how the integration and blending of data brings together if not connects causally more of the data that they have available to them. They combine different data sources to make sense of it, there is a process of getting a handle on the nature of the data visually (using often in Tableau the "show me" option) and then to bring them together and make sense of that perhaps by adding another layer of visualisation to make more sense of it[this is where you start putting the dashboards together into a story]. there seems to be first the ability to understand what the potential of the data to answer a question is, its relevance to your question or problem. P3 knows the data, where it is coming

The Unit designer is part of the process of reflexivity and is enabling the surfacing and making available for sharing of a department's unique way of knowing. This is part of building the organisations capacity for perspective making and then perspective taking.

On the other hand there was another tendency to create more complexity, P13 decried:

"And I have said to P1 that one of the problems that I have with the way in which it was done: they did things amazingly quickly, but the problem is that they are rolling stuff out very very quickly and not necessarily sitting back and reflecting. So everyday there is a new dashboard. And I want to say wait a moment why do we want to have that ... it's because someone has said that would be useful. So if we are not careful we will end up with 400 dashboards and it is so easy to get different views of things... let me show you an example quickly..." {P13 E5}

5.4.4.3 Sharing

The centrality of creating a representation in order to share is born out in the study. But the transition from making a representation and sharing it, is not as straightforward a process as (Boland & Tenkasi 1995) would like to indicate; considerations other than making the representation come into play and alter the design of the dashboard in order to facilitate and manage sharing. In response to being asked

if the dashboard that they had developed internally was being shared with others outside of his division, a manager reflected a common concern:

Well this is the big question. Statistics on their own I think are quite dangerous, so anything that I can use to make one argument others can use to make another argument. So for example, we are looking at the teaching hours' data what it seems to be saying is that my team do lots of teaching in October and November and then there is not so much in the rest of the year. So if someone outside can look at that: why have you got all these staff they are not doing anything during this period for the rest of the year. What it does not show is all the other stuff that they are doing out there... So there is this worry amongst some of my team about something like this being suddenly been made available to the rest of the University.” {P14E2}

There was a distinct pattern in the development of the dashboards internally to a unit or special interest group, where there was much “messy” work, graphs left unfinished abandoned in a sheet, revisions of data, reformatting of data, and so on, but out of which gradually grew something that made sense of their data. Then came a second process of tidying the dashboard up, systematically removing the anomalies and contradictions, provide as much context as it will allow, always in their minds is the notion of who will be reading these dashboards, effectively making all of the work entailed in perspective making invisible (Star 2010).

5.4.5 Achieving consensus

Being able to achieve consensus within a community is a mark of the maturity of perspective making. It is in the effort to establish a perspective that the majority of the usability feedback that the Planning Unit received from P13 in particular needs to be understood as he tries to ensure that the navigational and filtering are consistently applied.

But by far the biggest concern is to establish consensus is on the data. And as we have seen this is critical for making the data invisible and the nature of the conversation changes to be about what the team are going to do tactically. If there is a question about the data this becomes the focus of the discussion and without a tool like Tableau where the paradigmatic qualities of the data can be tested and verified it becomes difficult to establish that agreement.

P12: *So what P3 has done has created a new dataset underneath this... we still have the cumulative dashboard on a different turn but it is based on a different dataset. We had all this different data from different data sources and P1 has worked bring these altogether in one place live and cumulative in the same one.*

5.5 Perspective Taking

Perspective taking is the means by which a community of knowing with a mature perspective and practice can overcome its inward looking tendencies to take into consideration other perspective within the organisation. This is necessary for horizontal co-ordination of activities, for the co-operation between work units and importantly for the creation and sharing of new knowledge and innovation that comes from members of communities being able to step back from being immersed in their normal activities and reflect upon what is taken for granted and is no longer appropriate. It is in the ability of the unique knowledge work contained in each communities of knowing to be made accessible to other communities in support of collaboration between them that gives the capabilities of the organisation to respond to the changing environment.

5.5.1 The incommensurability of communities of knowing

(Boland & Tenkasi 1995) quote (Dougherty 1992):

"Nor is the problem like the proverbial set of blind men touching a different part of an elephant. It is more like the tales of eye witnesses at an accident, or of individuals in a troubled relationship—each tells us a complete story, but tells a different one"

The epistemic gap between functional units may not be as profound as that as between scientific communities to justify the full force of “incommensurability”, nevertheless it does seem present in the design and use of the dashboards and to play a significant role in the way communication across these boundaries is difficult and fraught with misunderstandings—extra work is necessary in order to achieve common ground. It is a common refrain expressed in:

If I am a librarian I know my librarian terminology, I don't know the Applications terminology.
{P14 E3}

In all my years I have never seen someone wanting another department's data {P1 E }

The Gartner report mentioned above points to another area of incommensurability to arise in organisations' move towards self-service, that between business units and IT. And to a certain extent this was reflected in the different approaches to the development of information dashboards pursued by the Planning Unit and IT. It is important to note that this study being focused on the design of the Tableau dashboards of which the IT department had no input is automatically from the perspective of the designers of the dashboard and is limited in its ability to represent IT's perspective.

Both P3a and P1 recognise and appreciate to a certain extent difference in perspective, attributing approaches to the management of data, from which tools and methodologies all flow, to “ideological differences”. The differences were apparent in various guises but mostly in the nature of what counts as data and what it was used for, and how best to structure it:

P13: *“the problem has been that we have never had very good data here. When P1 was appointed the first thing that she recognised that we needed was data sets that we could all agree on, we may not agree on every detail but at least we are all looking at the same data. So she and her team then started to develop numbers basically the dashboards things we could look at.”*

P3a: *“Our role is to separate the data from the transactional system and make it available to users.... I don't think that the departments know their own data well enough and that's the problem.”*

Another clear distinction was in the different timescales at which dashboards were designed and deployed and what can be expected out of a traditional data warehouse BI project. P3a was concerned to have all of the University's transactional data available to the business units, best provided by a data warehouse, but for the business teams involved in designing dashboards only the data that was immediately relevant to them counted, no formal structure of that data would suffice because its format had always to be adapted to the current, local need anyway and could not be specified upfront, nor is it a stable structure, evolving sometimes quite quickly with the questions that are now possible to ask in the very process of transforming and presenting data, as described in Vignette 1.

5.5.2 Reflexivity

From (Bruner 1986) comes a good description of the reflexivity that Boland & Tenkasi have in mind and its ability to move member's thinking beyond the limitations of a community's implicit interpretive schemes:

“It is this [metacognition] that permits one to reach higher ground, this process of **objectifying** in language or image what one has thought and then turning around on it and reconsidering it”.

First order reflexivity as I described above is still inward facing and reflects on the problems and puzzles, the methods, instruments and concerns contained within a perspective. But in perspective taking it is an outward facing mechanism by which other perspectives are taken into account and give members within a community the ability to change or overturn their own taken for granted rules, which requires the ability to reflect upon and renarrativise the familiar to open new insight and understandings. And this is possible when the product of that objectification is shared with others of another community.

It is difficult to find much direct evidence of this second order reflexivity, primarily because of the way in which perspective making seeks to restore the canonicity of a community of knowing. This gives a retrospective sense of linearity and steady systematic progress to the way in which each function or division within the University has developed its understanding of their domain and its relationship to the rest of the University using the dashboards. No interviewees had felt that their job had been fundamentally changed by their use of dashboards just made easier. But having said this it was noticed that sharing the dashboards especially with senior managers often brought with it a de-

gree of scrutiny and interpellation⁴, which induced a degree of reflexivity to answer. This can be seen in excerpt {P13E2} where P1 is being asked to explain how a dashboard could have produced such an anomaly. Less dramatically, as described in 5.5.3.1 below the purpose of getting feedback on dashboards from members in other communities is to invite another perspective on the dashboard and this can lead to an insight about what it is that they have assumed not immediately available to the community.

In Vignette 2 the applications teams were drawn into a reflexive process that was collaborative by the fact that they were aware of a serious decline in the number of applicants and had to develop a new perspective on the applications process.

During the interviews the process being taken through the use and an explanation of what elements meant for the interviewee was for the interviewer a perspective taking exercise, further questions and exploration of the implications of the interpretations was a form of hermeneutical enquiry. The dashboard and its use became a window or “hinge” into the form of life of the interviewee’s unit.

5.5.3 Boundary Objects

Boundary objects are key devices that emerge to facilitate lateral organisational forms and as I have tried to show, vertically too. What this study looks at is the impact that the social processes have on the design of the dashboards. If the construction of the boundary object is a social accomplishment (Star 1993) if and how the information dashboards and the Tableau server portal in which they are published, operate as boundary objects.

The fact that published dashboards are being used across functional boundaries is an indication that they are in part sitting between communities whether intentionally designed for this purpose or not. This use is clear in the server logs as described below and also in the way in which those interviewed would describe their use of the dashboards. It was striking how the same dashboard particularly the Applications Dashboard(s) was used by almost many in the University administration and Faculty but for slightly and not so slightly different purposes.

5.5.3.1 Feedback and modification of dashboards

There is a deliberate effort by the Planning Unit to adapt the design of the dashboard for which they were responsible and know would be used by several units by sharing with specific people, asking for feedback and taking this into consideration for the next iteration or tweaking of the design their recommendations. In this way these dashboards are an organisation wide collaborative effort. Here is a typical form of email exchange:

⁴ I am using loosely to mean a process by which the designing community is asked to explain the numbers with a review, if not confidence in that community’s functioning at stake.

Great stuff

A few immediate comments based on very quick play.

I still think levels would be better than years. When I combine the foundation year with the main programmes I THINK that the levels get mixed up (i.e. Level 3 FY are included with level 4 main progs). Likewise top ups?

The school filter - might be useful it that being set filtered the programme options. Very long list to scroll through.

This may be another dashboard, but **what I really want to see is** a year on year comparison. Can do it manually (so much better than nothing) but ...

On a general note, I think this is a bit cluttered (because the data s so complex). Might be worth thinking about an overview dashboard (thin one is good for getting to details).

P13

Hi P13,

Thanks for the speedy guinea-pigging!

On your first point. You are correct that if you include the foundation programme starters with the main UG cohorts you are comparing year 0 s with year 1s. The year in the report doesn't relate to the year of programme or the level of the modules being taken. It simply shows what that cohort of students is up to the year they start, the following year etc

We didn't use the 'level' because in some schools year 2 students can do year 3 modules. P3 has introduced a freshman, sophomore, senior concept which is sitting in the background report. I'll have to check with P3 how that works with foundation years. In the meantime you can identify this lot with the filter.

On your second point - will do

On the third point - I like the idea of a time series summary with detailed perspectives on other tabs. We will make a note of that for version 2.

Thanks again. And keep the comments coming.

In Vignette 2 the Applications dashboard can be seen to operate as a boundary object between the various functional units related by their various roles in the recruitment process, are able to find a way in which they bring their various perspective into dialogue.

P9 gives a particularly vivid but not unique (see Vignette 2 excerpt “[W]hat tends to happen now is that each Dean will have their ipad or laptop open for their own school and they will be looking at their own data and so the conversation has moved on from me explaining to everybody where we are to having a conversation about what the tactic needs to be for each of the areas.” above) description

of how the dashboard operates as such when describing how she uses it from her perspective and how this forms the basis for discussions around co-ordinated actions in response to what the dashboards reveal:

“...Well I usually look at it by myself and I point other people to look at it if there is something worrying or something I want them to look at. The truth is that this is the data that is being looked at regularly by all the exec and my director and we look at it together anyway. So there are meetings, recruitment specific meetings, there’s the recruitment task force and a series of other meetings related to this and we look at this actively as a bigger group

Interviewer: Then do you look at the same dashboard and discuss?

P9: Sometimes, I think mostly people look at it themselves and then draw conclusions and then we discuss those.

Interviewer: How do you decide which is the better interpretation or conclusion to draw?

P9: I think whoever has a stronger point and evidence so the discussion around Education Studies I have been banging on about that for quite a long time, and I think it is now widely excepted that [a causal link has been established between a tactic they had been pursuing and a specific outcome] but irrespective of the outcome I have to drive more applications. So we don't tend to argue about this as long as we can agree on what it is that we can do and most of the time we can. I have not been in a situation where we cannot agree on how do we react to what we are seeing... We agree on the response type” {P9E3}

Note that perspectives are preserved by their separate review and interaction with the dashboard prior to meetings and this becomes the basis for dialogue-driven perspective taking during meetings. Consensus (around causal factors) is not necessary for co-ordinated action to take place, even so the consensus alluded to, if that is what it is, is hard won and grounded in and tested by various perspective and interpretations of the data.

5.5.3.2 The server logs

Use of the dashboards are logged and become useful resources in coming to understand how who use the dashboards and when. Analysis of the dashboard usage is a window into the knowledge net of the organisation. While a lot more analysis is possible what was obvious is that dashboards that are publicly available are looked at across the university and not just by those for whom they were built. The second is that people use multiple dashboards, and it seems that they have different profiles of use, in frequency and configuration of dashboards accessed. Together these two observations would indicate that dashboards are being used as boundary objects to varying degrees capable of satisfying users’ information and work related needs.

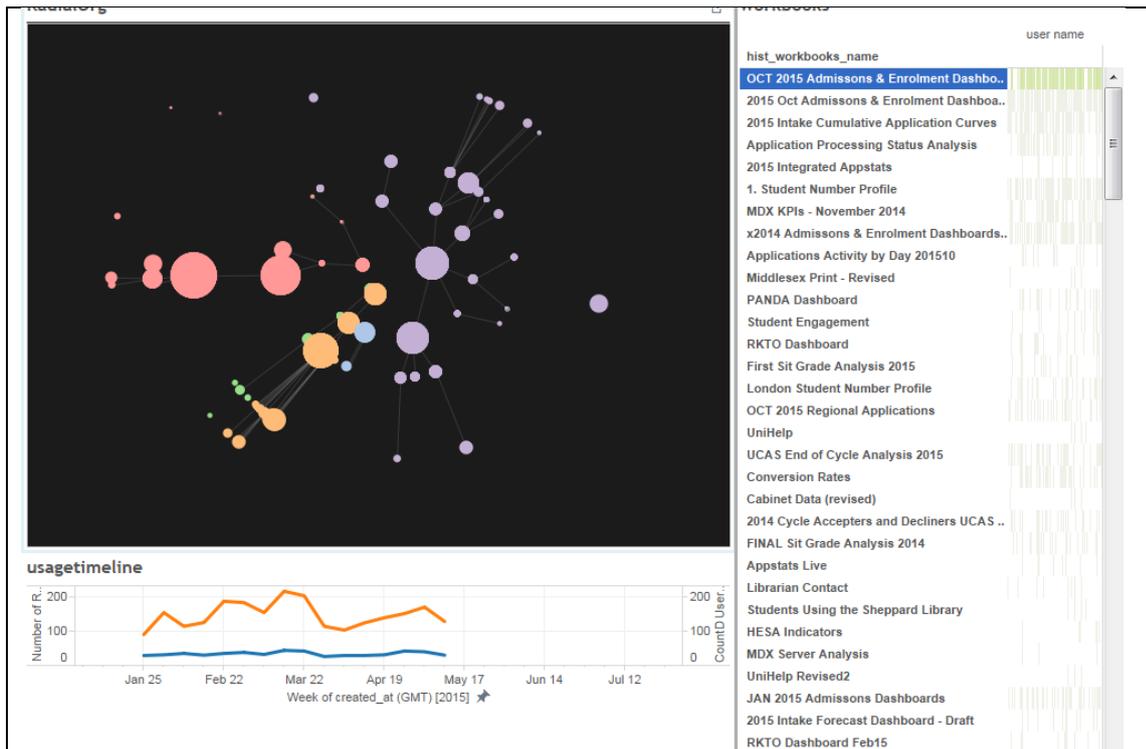
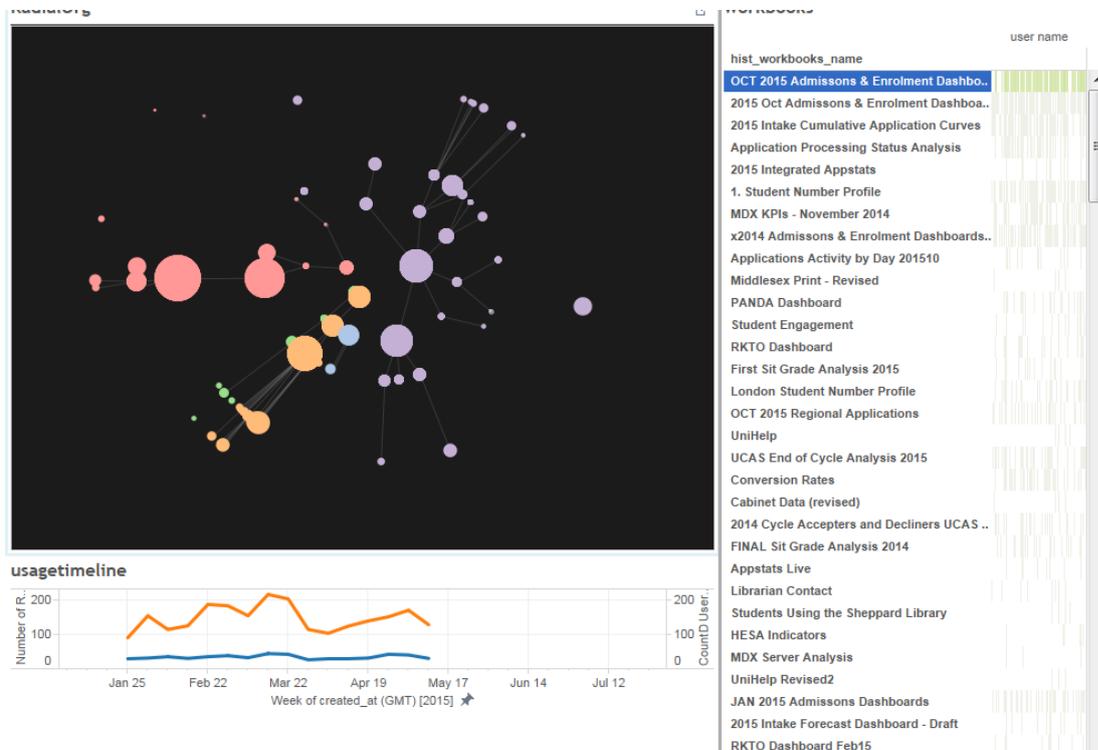


Figure 10 Server Log Dashboard

Representing the use of dashboards by staff in a radial formatted organogram. Colours represent different units, the centre is the VC and the outer rim operational staff. The dots represent individual users and their size indicates the number of accesses over the period recorded (usagetimeline)

The Applications dashboard (see



Figure

10 Server Log Dashboard) and its iterations are used widely in the organisation, across several func-

tions (different colours) and at many layers of management right down to the operational level (at the outer most circle).

5.5.3.3 Architecture of boundary objects and dashboards

To repeat according to (Star 2010) the general architecture of boundary objects include:

1. An interpretative flexibility:

This was vividly demonstrated by the use of at least two managers from different departments of the same mark (Figure 9. Cumulative Curve of Acceptances of Offers) to assess the impact of the work of their efforts.

2. As having emerged out of the information and work requirements of communities:

Here I can refer to “*crucial, prior to this we had virtually nothing, we didn't have anything that you could look at routinely which meant that you could never track changes*”. {P13E1} where P13 mentions the significance of having a means of tracking overall changes which is less significant for P12 as shown in {P12E1} whose own requirements are much more specific and only marginally represented in the same dashboard.

3. As enabling the dynamic between the ill-structured, vague and common (or communal) use of the object, with the well-structured, specific, tailored and local uses of the object respectively.

This was built into the dashboards in a number of ways, by having high level views and much more granular views of the data, by interacting with the data by filtering and selecting and by being able to drill down into the data. These were some of the mechanisms that allowed users to adapt the dashboard to their own particular local and precise uses. And these were features that came out of the feedback and requests from the end-users. There was another instance where end-users would use a range of dashboards together, getting particular information from particular dashboards, a further analysis of the server logs is likely to reveal user profiles.

5.5.3.4 Boundary object typology and dashboards

(Star 1989) describes four types of boundary objects and later (King & Star 1990) articulates how these types might be articulated in a Management Decision Support System. This has some relevance to the architecture and purpose of the dashboards and bears further investigation in future work.

5.5.4 Semiotic Brokers

The Planning Unit as the owner of the Tableau Project acted as “semiotic brokers” facilitating the perspective taking process by supporting the development of dashboards. P1 described at least three ways

in which the Unit would typically establish end users requirements and then work with them to deliver on the development of their own dashboards and collectively used dashboards:

5.5.4.1 Pair Analytics

One of the more sophisticated end users (indicating a mature perspective making and the ability to represent visually) gets in touch with P2 or P3 and arranges a time to sit with them and work on the thing they need (this generally happens on an ad hoc basis and involves two people sitting at a desk looking at a screen together

5.5.4.2 Translators

P4 or P1 could be in a meeting where an issue is being discussed by members of the ex-ec/deans/deputy deans/service colleagues and a question that people don't know the answer to comes up. In that situation the 'end user' might be a group of 5 or more senior colleagues who are interested in the question. What generally happens is that one of them works the question into a reporting requirement and comes back to the office to work with P2 and/or P3 to develop the dashboard that answers the question on behalf of the end users. Once the Unit has a mock-up of the solution they will either email it to a few of the people who raised the question or show it to them next time they see them in order to get feedback without them necessarily being aware that they are part of the development cycle.

5.5.4.3 Interpellation

An end-user spots that a dashboard is producing odd/wrong results or has a suggestion about a visualisation and filter. They either email P2 or say something to one of the team in a meeting. Where possible they look into the issue and correct it.

P1 said that they do not form part of the traditional BI structure, where the business analyst works together with business users, neither were they brokers that develop a requirements list that is then implemented by IT. Her advantage lay in the fact that she was there to help with the strategy of the business and was able to identify a lack of information necessary to inform a decision, turn this requirement into a BI problem that could be implemented in a dashboard. On the whole though the Unit through the process of organising and making available data and being involved in the building of several dashboards that stretched across several departments, and in supporting other units develop their own dashboards had a much wider and much more granular view of the organisation than management or any one unit. In this way it occupies middle ground between them, having to take many perspectives into account as it did its work.

5.5.5 Perspective taking in action

This does not mean to be a comprehensive list of the ways in which the dashboards were used as part of perspective taking partly because of the limited number of interviews and observations in one organisation. It may not even be possible to give a taxonomy of the uses because it is highly dependent on the social configuration. Nevertheless what I hope to show is that the dashboards have a role not only within a community of knowing but also between communities and this can take some surprising and unanticipated forms.

5.5.5.1 Break down and recovery

The kind of break down relevant to perspective taking occurs between communities when they are unable to reconcile their qualitatively different interpretations of something that is in common to them both.

But break down also happened in less dramatic forms around what get surfaced as usability issues. Not all usability issues are social and some clearly have to do with the technical qualities of the dashboard, like the size of the font, the degree of clutter and the difficulty of selecting items. But even these have to be seen in the context of the activity that defines the use to which the dashboard is put.

There were a number of ways in which break down could be repaired which indicate that another perspective has been taken into account: by incorporating the recommendation or request into the dashboard, by creating a new set of graphs and putting these into a new view of the dashboard, by designing the dashboard or giving a slightly different version of it. The role that the Planning Unit played as semiotic brokers was crucial in repairing.

5.5.5.2 Collaboration

In Vignette 2 the collaborative effort to analyse the causes of the decline in applications involved an intense exercise over a couple of days in which analysis reveal something that needed or could only be explained by asking some from another unit. It is interesting to note that P1 said that in retrospect, it may have been regarded as collaboration, at the time it felt more like interrogation, nevertheless a robust understanding of the causes was established, sufficient to secure agreement on a course of action.

5.5.5.3 Interpretive reading

Interpretive reading describes the effort by members of one community of knowing to understand, the communications of another community of knowing by “subjecting [them] to re-reading in the hopes of portraying the tacit and implicit meanings characterising a community of knowing.” Boland & Tenkasi (1995) p367. The dashboards played a critical role in facilitating this interpretive reading and its usefulness for other communities of knowing.

A manager was taking the researcher through the applications dashboard, filtering for her purposes she was reading off some key metrics for their department and reflecting on and narrating their interpretation of their situation.

This is very interesting to see what is happening here and here, you see there is a change in behaviour that actually started here but the concept that well we have automated offer levels we have started to send automated offer letters which allow students to accept an offer much easier. You can see that from that moment there is a delay acceptances have started at a different angle because it is related to offers been given quicker as well but in the past and offer would have been sent to an applicant but it was sent to an applicant later in the process of accepting an offer would be much more difficult. Now offers been given that is emailed to student on the same day and they can just click a button to respond. So there is an instant correlation n Whereas in the past there wasn't such a strong correlation {P9E4}

Another senior manager within the Library services (P14) was talking about his use of a dashboard designed by and for the Admissions administrative team:

And I am also aware of other work that is going on which feels like I can feed into and help with [student engagement] I guess this one is not in LSS because it is a cross university project even though it is one of the people in L SS that were on the project. So what is very interesting about this is that it is using data about student interactions with the University to look for warning signs of students who might be withdrawing, but I want to use the same kind of data to see how they are engaging with us and then analyse it to see whether we have can map an impact

I would use the same dataset but in a slightly different way towards a different end. And I feel rather than doing something completely different over here [at L SS] we can do it all together in the same place

5.5.5.4 Negotiations

P13 on the applications dashboard was now able have conversations with for example the Director of Estates, Time tabling , Finance because “they will be providing me with the resources, but historically I'd have been saying that my needs will be going up next year. Now I can show them, they can play with it, they can challenge it and say yes but ... and then we can have a conversation about it and they would give me a whole hosts of reasons why I didn't need space ... so we would have those conversations which we could never have before”. {P13 E }

5.5.5.5 Expanding Span of Accountability

In Vignette 3 working with data that came from Timetabling and making this part of the analysis not only reveal the interdependence of the two unit but extended its accountability because it reveal

something about the effectiveness of that department, adding the data that Timetabling gets from the faculties extends accountability further. Adding student attendance data to the dashboard puts Facilities in a position to evaluate from its perspective an element of the performance of lecturers. The dashboard has the potential to reconfigure the knowledge net between at least three units.

5.5.5.6 Contributing

P14 wants to add to a dashboard already established, integrate some of his data with the dashboard in this way it becomes a repository for multiple communities of knowing can access.

5.5.5.7 Appropriation

P14 takes an interpretative reading of the applications dashboard translating its indicators into implications that it might have for his department's planning and resource allocation.

5.5.5.8 Repurposing

Having access to a range of dashboards already built was often regarded as a major resource for builders of dashboards, and there was often a comment about getting ideas from how others had represented data, if not actually taking a graph as a starting point for building their own.

5.5.5.9 Scrutiny and Interpellation

Building a dashboard and sharing it with other communities is fraught with a certain amount of danger

P16: felt that initially a lot of trust in her department was lost due to the inconsistencies that P13 was able to point out between the data in her dashboards and what he knew of directly in his own department. But as a consequence the data and its structure were

P9: there is a need to sanitize the dashboards before they were happy to share the dashboards, to make sure that they could defend any interpretations

P1: there was a standard practice in the design of a dashboard of first asking those people whose unit's performance is represented in a dashboard for comments and design input before releasing it to the manager that had requested it, so that a graph could be understood in context and unfavourable conclusions are not so easily drawn from too simplistic a metric.

In Vignette 3 The building of the Occupancy dashboard reveal the network of dependencies that Facilities had on the work of other departments like Time tabling and the Faculties.

6 Discussion

The primary purpose behind the initiation of the Tableau project was to create better management reporting that are the cornerstone of establishing a better performance and measurement system for the implementation of the University's strategy. This is a top down management driven process, taking a strategy converting that into a plan and operationalising it as a suite of measures for the purposes of control. While there may have been concerns from management for performance measurement and control this was not typically how the dashboards were built at the University.

It seems that there was rather a bottom up process where dashboards were developed locally as instruments of perspective making and then migrated outwards and upwards following the knowledge creation spiral of (Nonaka et al. 2000), very much supporting Mintzberg's view on strategy formation as an emergent practice.

This reality about the use of the dashboards also explains why usability issues remain tolerated and limits on the amount of effort that goes into fixing them are according to the 80/20 rule rather than optimisation –simply because it is adequate to the task.

Nevertheless there are limitations in the model described by Boland & Tenkasi (1995) and we will need to turn to other theories for better descriptions. What is not taken into account is how the representation that is so necessary a catalyst for a reflexive discourse, actually works to do that. Neither is it clear how the new knowledge that a community gets to be embedded in the organisation and how this might itself constrain negatively or positively on the formation of communities of knowing. They expressly exclude looking at these questions in their paper but this is also to miss quite important characteristic of communities. Activity Theory (Engeström 1987; Bertelsen & Bodker 2003) addresses some distinct weaknesses and needs to be added to the analysis of how dashboards re designed and used.

There is a heavy reliance on the mutuality of communities making representations and sharing to enable perspective taking in other communities. It seems from the research that as long as a community is producing a dashboard and sharing, perspective taking in other communities is enabled. Although it does help give a deeper appreciation for what is entailed in building a dashboard which in turn supports perspective taking.

Another limitation of the model revealed in the data is the way in which they conceive of separate forums (Narrative, Representation, Interpretive, Theory-building Forums) focusing on different elements of and supporting perspective making and perspective taking, It seems in the data that the dashboards allow these activities to take place simultaneously.

One thing that the study reveals is that perspective making can take place within a well-established community of knowing like a functional unit. It can just as well form a community of knowing that stretches across functional units.

The use of the dashboards as an integral part of the process of complexification is not adequately account for in perspective making and taking model and this is because the model emphasises the cognitive and social dimensions to knowledge creation above the material. It therefore misses the critical role that artefacts like dashboards play in perspective making and has to describe a unique class of objects called knowledge representations, which somehow become boundary objects when shared. But not all boundary objects are knowledge representations. This does not weaken the fundamental insight contained in the idea of perspective making and perspective taking; it only limits the forms that these dynamics can take. A deeper understanding of the role of objects will enrich the model. What the model also misses is the way in which in the process of sharing their dashboards members of a community change their design concerns, as they encountered interpretation problems and usability issues.

The research has reveal the limitations of the model, having itself opened the study data to the subtle dynamics of knowledge creation and sharing.

The dashboards may not be fully fledged knowledge visualisations in the sense described by (Eppler 2011) or implied by (Boland & Tenkasi 1995) namely fully conscious efforts to represent what is known, but they still operate to stimulate that crucial reflexivity necessary for questioning the frame, elaborating the frame (complexification) and reframing as described by (Klein et al. 2006) which underlies the organisational capability for innovation.

6.1 Recommendations

We can make certain recommendations based on the observations and the model as articulated in the context of the Tableau Project.

For example in Vignette 3 if the occupancy dashboard is shared with those P7 wants to share, it could become a boundary object.

A major problem at the University is the availability of space for lecturing and teaching. Achieving optimal occupancy is a product firstly of Recruitment, secondly of the various Schools' ability to plan its courses, thirdly Timetabling and finally Facilities Management. There are several options that the University will need to consider. Perhaps it will need to invest in more space but would it perhaps be better to determine if capacity is in fact the problem? So how does the University determine options? The problem is that it is not solved by the knowledge of any one function because each will have its own criteria for success which can be met without regard for interdependencies. Neither will imposing a performance measurement framework from above solved problem. Here work needs to be across

practices, each function must find a way of collaborating that is second order knowledge work. What is needed is an adequate boundary object to facilitate this perspective taking.

. If they are to form a new community of knowing, looking perhaps at the inter-dependencies of the departments around space and occupancy, the dashboard will have a very important role to play and its evolution (including the addition and alignment of other data sources like student attendance) will mark the development of the cross-functional team in understanding the correlations and causalities of their interdependencies. This exercise of perspective taking through feedback and discussion will reconfigure the knowledge net and therefore the relationship that the core units have with each other. Eventually these relationships will become stable and the development of the dashboard will achieve a symbolic adequacy, come to embody that understanding and serve to co-ordinate the various functions independent routine practices and policies.

By having the dashboards available publicly, functions downstream have access to an understanding of the potential impact that upstream innovations will have on them, potentially allowing them to participate in jointly transforming knowledge at pragmatic boundaries, so that those that are responsible for creating upstream innovations are able to get some sense of the implications that this has for downstream delivery before it is part of the student experience. So for example having a branding strategy and positioning the University in a certain way needs to be backed up by service delivery downstream, if these are incongruent the effectiveness of the brand exercise will be diminished. The dashboards then become a site in which negotiation can take place and perspective taking emerge. This is something that cannot take place at the management level because at this level the depth of understanding of the operations of the functions is not, nor need to be understood.

This also means that those dashboards developed for management may not be adequate for cross-functional work and only those that have been developed within a function first and then exposed to feedback and modifying dialogue are necessary. Functions need to be supported in the development of the dashboards and spaces have to be created in order for feedback and boundary spanning work to be done around the development of those dashboards.

7 Conclusion

7.1 Summary

What this research has sought to do is contextualise the development and use of dashboards within the University as part of a trend that sees a shift in power away from IT to end users through self-service data and analytic software tools. It has done this by problematising the notion of self-service using the Boland & Tenkasi (1995) model. This model has been applied as a lens through which to look at the way in which the dashboards have been designed and used by people in the context of their normal work. This has illuminated the social dynamics of the design process, showing that it is not a straightforward process of individuals gaining access to data and having sophisticated but easy to learn tools to make sense of that data. It entails rather something of a paradigm shift in the movement away from the traditional long BI development cycle presided over by IT and involves complex and subtle forms of social interaction within business units and between them. (Star 1993)

The perspective making and taking model has proven a fine-grained instrument for unpacking these dynamics and the impact they have on the design and use of information dashboards—it seems that the model describes something fundamental about the way in which people do knowledge work in complex heterogeneous context such as a University.

This research has showed that information dashboards, as they have been deployed, are good examples of information technology supporting perspective making and perspective taking and therefore of knowledge creation and sharing within the University.

In addition, the findings have shown some limitations in the model, particularly in that it misses the significance of the role of the dashboards have as analytical instruments in perspective making. Further concepts applied to the basic principles of perspective making will enrich the model though.

The dashboards are used primarily in two ways in distributed cognition environments: to deepen an understanding of a certain domain (making a perspective) and to facilitate knowledge exchanges across epistemic boundaries, in fact to create new knowledge across boundaries (taking a perspective). P14 said that Tableau had sold itself by being something that they needed rather than by being driven as behemoth top down system.

By articulating the notion of a community of knowing the model helps us understand why it is important that communities first develop a perspective by being allowed to design and manage their own dashboards.

With the concept of perspective making we can see the role of Business Intelligence and Analytical tools supporting the paradigmatic analytical form of cognition and how this is interwoven with the equally important social processes of narration. Narration is the means by which people make sense of

the changes that occur in their environment, revealed by the paradigmatic analysis, and out of which appropriate action make sense. The problem of relating analytics to action, a feature of information processing models of business intelligence theory and practice, is a nonissue if one understands how narration and paradigmatic analysis are interwoven in the form of life that makes up a community's practice and gives it its identity.

With the concept of perspective taking we can see the extra work entailed in cross boundary work, is also about creating strategic alignment within the organisation, it allows co-operation while maintaining the integrity and therefore unique role of each unit. Beyond this it allows for the transformation of units as they both confront the contradictions within their own practice and make available for innovation that very knowledge that their practice allows. We can see the importance of boundary objects and how dashboards can act as such.

By closely involving the end-users in the design process through the idea of self-service, members of communities have designed the dashboards to suit their purposes more precisely. In perspective making the design focus is on insight derived through analysis and the sense-making power of an evolving narrative, when it comes to perspective taking the dashboards are modified to take more perspectives into account through feedback and addressing usability issues.

Perhaps the greatest advantage of the introduction of Tableau within the organisation has been the way in which the building processes has facilitated a heightened reflexivity—the ability for the organisation to look at itself, the way in which it does things, with an intense focus. In short self-service is nothing short of organisational knowledge creation and organisational development and is the primary mechanism by which individuals, communities and the organisation can respond innovatively to the changes in the operating environment.

7.2 Evaluation

The ethnographic inspired approach led early on to the realisation that a socio-technical analysis of the introduction of the Tableau platform at the University was the most appropriate to understand the range of object-centred knowledge work that is a social accomplishment. As such, this research has contributed to that long tradition that says that the uses of technology cannot be understood by looking at individuals in isolation, and only make sense when one makes the social dynamics centre stage to the analysis and design of it.

The unique contribution of this study is to demonstrate that dashboards are used to create new knowledge within and between communities and make relevant parts of that knowledge available across the organisation. The variety of evolutionary trajectories of the dashboards is evidence of the complex role that they play in the knowledge ecology of the University. There is evidence that some start local to a community of practice operating something like an epistemic object and then become a

boundary object connecting that community to others and are tweaked in the design to incorporate those other perspectives. Dashboards can be designed to function primarily as boundary object as in Vignette 2 where the applications dashboards stretches across several interdependent communities. Dashboards that are functioning as boundary objects can be used in part to be made epistemic objects as data and graphs are appropriated and repurposed for a community's own perspective making. Dashboards are used also as technical objects to monitor and support local operational practices if users are allowed to drill down into the raw data. Dashboards that are acting as boundary objects specifically for a group can become organisational resources and put to uses beyond their current purposes.

So the notion of self-service as coined by Gartner, with its implied focus on the individual analysing data, is a limited description for the range of socially driven practices associated with a shift in power to the end-users afforded by tools like Tableau. As such it is difficult to see how companies can design technology road maps based on what the technology can potentially do rather than a deep appreciation for the social practices that drive its adoption. What drives the social practices is the unique knowledge work that an organisation needs to accomplish in order to remain competitive.

7.3 Future Work

Future research needs to look at other theories of objects for a deeper understanding of the role of representations for perspective making. Future research ought to look at tracking and mapping other trajectories of dashboards and it may be valuable to look at the work of Snowden & Boone (2007) in this regard as well. It would be useful to determine if the use of dashboards for perspective making and perspective taking extend to other industry sectors besides higher education and to look at the impact that other contexts have on their design.

This study has looked at a relatively straight forward analytical problems faced in the day to day operations and medium term planning of activities of the University, while it has been a huge improvement in the management information system it is already clear that deeper insight is needed and more sophisticated analysis of the data is necessary. The turn toward a more sophisticated analytical tools and the introduction of advanced statistics and computational techniques beyond the expertise of those responsible for the reporting, introduces a level of complexification that is qualitatively different. In order to use the data at hand to predict when for example students are most likely to drop out is beyond the capabilities of the dashboard and even experienced users. This is to introduce another community of practice into the mix and what for many is an opaque computational agency to the distributed cognition environment.

The question of integrating the analysis of data into the decision making process of business users, turns on the distinction that is made between what human beings can do well as opposed to what can be relied on for computers to do. This is important because there is a great deal of hope (and perhaps

for many a fear too) in modern algorithms to do with great ease and greater accuracy what human beings find tedious and increasingly impossible to do well.

Further research is required to understand how the user interprets and uses the sophisticated algorithms without undermining their expertise and the tacit knowledge that is so important to the knowledge of the organisation and its ability to respond creatively and innovatively to a dynamic environment.

Big data throws into relief this divide, it makes it more pronounced because the technology and the practices of BI are inadequate to the task, and there emerges a new skill embodied in the mythical beast of the data scientist. The data scientist has to do all the boundary work, much of this is new and emerging, and forms a serious constraint on organisation's ability to make sense of data.

Without a deeper understanding of the social aspect of the visualizations produced as part of the analysis, their utility as a boundary object is diminished especially in their ability to tap into the tacit expertise of business users. This could lead to superficial analysis and ultimately the abandonment of analytical projects.

8 References

- Attfield, S.J., Hara, S.K. & Wong, B.L.W., 2010. Sensemaking in Visual Analytics : Processes and Challenges. *International Symposium on Visual Analytics Science and Technology*.
- Bannon, L.J., 2000. Understanding Common Information Spaces in CSCW. *Workshop on Common Information Spaces*.
- Bertelsen, O.W. & Bodker, S., 2003. CH 10 Activity Theory. In *HCI Models, Theories, and Frameworks*. pp. 291–324. Available at: http://mail.free-knowledge.org/encyclopedia/activity_theory.html%5Cnhttp://www.interaction-design.org/encyclopedia/activity_theory.html.
- Blue Hill Research, 2015. *Anatomy of a decision.*,
- Boland, R.J. & Pondy, L.R., 1983. Accounting in organizations: A union of natural and rational perspectives. *Accounting, Organizations and Society*, 8(2–3), pp.223–234.
- Boland, R.J.R. & Tenkasi, R. V., 1995. Perspective making and perspective taking in communities of knowing. *Organization Science*, 6(4), pp.350–372.
- Bowker, G.C. & Star, S.L., 1999. *Sorting Things Out Classification and its consequences*, Massachusetts Institute of Technology.
- Braun, V. & Clarke, V., 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), pp.77–101. Available at: http://eprints.uwe.ac.uk/11735/1/thematic_analysis_revised_-_final.doc [Accessed May 25, 2014].
- Bruner, J.S., 1990. *Acts of Meaning*, Harvard University Press.
- Bruner, J.S., 1986. *Actual Minds, Possible Worlds*, Harvard University Press. Available at: <https://books.google.com/books?id=Ce0PXtac1egC&pgis=1> [Accessed March 13, 2016].
- Card, S.K., Mackinlay, J.D. & Shneiderman, B., 1999. *Readings in Information Visualization: Using Vision to Think (Interactive Technologies)*, Morgan Kaufmann Publishers In. Available at: <http://www.amazon.co.uk/Readings-Information-Visualization-Interactive-Technologies/dp/1558605339> [Accessed October 16, 2012].
- Carlile, P.R., 2002. A Pragmatic View of Knowledge and Boundaries: Boundary Objects in New Product Development. *Organization Science*, 13(4), pp.442–455.
- Carroll, J.M. ed., 2003. *HCI Models, Theories, and Frameworks: Toward a Multidisciplinary Science*, Morgan Kaufmann Publishers. Available at: <http://dx.doi.org/10.1016/B978-1-55860-808-5.50020-4>.
- Crandall, B., Klein, G. & Hoffman, R.R., 2006. Working minds. *A Practioner's Guide to* Available at: http://library.mpib-berlin.mpg.de/toc/ze_2006_1423.pdf [Accessed December 5, 2014].
- Creswell, J.W., 2012. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* 4th ed., Sage Publications Inc.
- Davenport, T.H. & Harris, J.G., 2007. *Competing on Analytics: The New Science of Winning*, Harvard Business School Press. Available at: <http://www.amazon.co.uk/Competing-Analytics-The-Science-Winning/dp/1422103323> [Accessed October 2, 2013].
- Deloitte, 2015. Making the Grade 2015 - Key Issues Facing the UK higher education sector. Available at: [- 76 -](http://www2.deloitte.com/content/dam/Deloitte/uk/Documents/public-sector/deloitte-uk-</p></div><div data-bbox=)

making-the-grade-2015.pdf.

- Dougherty, D., 1992. Interpretive Barriers to Successful Product Innovation in Large Firms. *Organization science*, 3(2).
- Dreyfus, H.L., 1992. *What Computers Still Can't Do: A Critique of Artificial Reason*, MIT Press. Available at: <https://books.google.com/books?id=7vS2y-mQmpAC&pgis=1> [Accessed January 23, 2016].
- Engeström, Y., 1987. Learning by Expanding. *Helsinki: Orienta-Konsultit Oy*, p.368.
- Eppler, M.J., 2011. What is an effective knowledge visualization? Insights from a review of seminal concepts. *Proceedings of the International Conference on Information Visualisation*, pp.349–354.
- Eppler, M.J. & Burkhard, R. a., 2007. Visual representations in knowledge management: framework and cases. *Journal of Knowledge Management*, 11(4), pp.112–122.
- Ewenstein, B. & Whyte, J., 2009. Knowledge practices in design: The role of visual representations as “epistemic objects.” *Organization Studies*, 30(1), pp.07–30. Available at: <http://oss.sagepub.com/cgi/reprint/30/1/07>.
- Few, S., 2006. *Information dashboard design. The effective visual communication of data* C. Wheeler, ed., O'Reilly. Available at: http://www.amazon.co.uk/Information-Dashboard-Design-Effective-Communication/dp/0596100167/ref=sr_1_3?s=books&ie=UTF8&qid=1415378945&sr=1-3 [Accessed November 7, 2014].
- Fields, B., Amaldi, P. & Tassi, A., 2003. Representing collaborative work: The Airport as Common Information Space.
- Fields, R. & Wright, P., 2000. Editorial: Understanding work and designing artefacts. *International Journal of Human-Computer Studies*, 53(1), pp.1–4. Available at: <http://www.sciencedirect.com/science/article/pii/S107158190090377X>.
- Henderson, K., 1991. Flexible Sketches and Inflexible Data Bases: Visual Communication, Conscription Devices, and Boundary Objects in Design Engineering. *Science, Technology & Human Values*, 16(4), pp.448–473.
- Hutchins, E., 1996. *Cognition in the Wild*, Available at: <http://hci.ucsd.edu/hutchins/citw.html>.
- Keim, D.A. et al. eds., 2010. *Mastering the Information Age Solving Problems with Visual Analytics*, Eurographics. Available at: http://books.google.com/books?hl=en&lr=&id=vdv5wZM8ioIC&oi=fnd&pg=PA1&dq=Mastering+the+information+age:+solving+problems+with+visual+analytics&ots=yR-hK4giDR&sig=s_hFbaREP5SSdK0VMtyD9sLjpbY [Accessed November 12, 2012].
- King, J.L. & Star, S.L., 1990. Conceptual foundations for the development of organizational decision support systems. *Twenty-Third Annual Hawaii International Conference on System Sciences*, iii.
- Klein, G., Moon, B. & Hoffman, R.R., 2006. Making Sense of Sensemaking 2: A Macrocognitive Model. *IEEE Internet Computing*, 21(5), pp.88–92.
- Kuhn, T., 1970. *The Structure of Scientific Revolutions*, 2nd enl. ed. Available at: https://scholar.google.co.uk/scholar?hl=en&q=kuhn+Scientific+revolutions&btnG=&as_sdt=1%252C5&as_sdt=#1 [Accessed February 29, 2016].
- Latour, B., 1987. *Science in Action: How to Follow Scientists and Engineers Through Society* - Bruno Latour - Google Bø,
- Lave, J., 1988. *Cognition in Practice*, Cambridge University Press.
- Lave, J. & Wenger, E., 1991. *Situated learning: legitimate peripheral participation: Learning in doing*, Cambridge University Press.

- Munzner, T., 2014. *Visualization Analysis & Design*, CRC Press.
- Nardi, B., 1996. Activity theory and human-computer interaction. ... *consciousness: Activity theory and human-computer ...*, pp.4–8.
- Neumann, L.J. & Star, S.L., 1996. Making Infrastructure : The Dream of a Common Language. , pp.231–240.
- Nicolini, D., Mengis, J. & Swan, J., 2012. Understanding the role of objects in cross-disciplinary collaboration. , 23, pp.612–629. Available at: <http://dx.doi.org/10.1287/orsc.1110.0664>.
- Nonaka, I. & Krogh, G. von, 2009. Perspective—Tacit Knowledge and Knowledge Conversion: Controversy and Advancement in Organizational Knowledge Creation Theory. *Organizational Science*, January.
- Nonaka, I., Toyama, R. & Konno, N., 2000. SECI, Ba and Leadership: a Unified Model of Dynamic Knowledge Creation. *Long Range Planning*, 33(1), pp.5–34. Available at: <http://www.sciencedirect.com/science/article/pii/S0024630199001156>.
- Oswick, C. & Robertson, M., 2009. Boundary Objects Reconsidered: from Bridges and Anchors to Barricades and Mazes. *Journal of Change Management*, 9(2), pp.179–193.
- Simons, R., 2000. *Performance Measurement & Control Systems for Implementing Strategy*, Prentice-Hall International.
- Snowden, D.J.D. & Boone, M.M.E., 2007. A Leaders Framework for Decision Making. *Harvard Business Review*, pp.69–76. Available at: <http://aacu-secure.nisgroup.com/meetings/ild/documents/Symonette.MakeAssessmentWork.ALeadersFramework.pdf> [Accessed October 29, 2014].
- Star, S.L., 1993. Cooperation without Consensus in Scientific Problem Solving: Dynamis of Closure in Open systems. In S. Easterbrook, ed. *CSCW: Cooperation or Conflict*. Springer.
- Star, S.L., 1989. The Structure of Ill-Structured Solutions: Boundary Objects and Heterogeneous Distributed Problem Solving. In *Distributed Artifidal Intelligence*. pp. 37–54. Available at: <http://portal.acm.org/citation.cfm?id=94081>.
- Star, S.L., 2010. This is Not a Boundary Object: Reflections on the Origin of a Concept. *Science, Technology & Human Values*, 35, pp.601–617.
- Star, S.L. & Griesemer, J.R., 1989. Institutional Ecology , Translations ’ and Boundary Objects : Amateurs and Professionals in Berkeley ’ s Museum of. , 19, pp.387–420.
- Thomas, J.J. & Cook, K.A., 2005. *Illuminating the Path The Research and Development Agenda*, IEEE Press. Available at: <http://nvac.pnl.gov/agenda.stm>.
- Tufte, E.R., 1995. *Envisioning Information [Hardcover]*, Cheshire Conn.: Graphics Press. Available at: http://www.amazon.co.uk/Envisioning-Information-Edward-R-Tufte/dp/0961392118/ref=la_B000APET3Y_1_2?s=books&ie=UTF8&qid=1393781953&sr=1-2 [Accessed March 2, 2014].
- Weick, K.E., 1995. *Sensemaking in Organizations (Foundations for Organizational Science)*, Sage Publications, Inc. Available at: <http://www.amazon.co.uk/Sensemaking-Organizations-Foundations-Organizational-Science/dp/080397177X> [Accessed December 12, 2012].
- Wenger, E., 1998. *Communities of Practice Learning, Meaning, and Identity*,
- Winograd, T. & Flores, F., 1986. *Understanding computers and cognition : a new foundation for design*, Norwood N.J.: Addison Wesley. Available at: <http://www.amazon.co.uk/Understanding-Computers-Cognition-Foundation-Design/dp/0201112973> [Accessed July 28, 2013].

Appendix 1 Sample questions to ask interviewees who were dashboard users

1. What were the major problems that you were trying to solve with the dashboards
2. who was demanding this report or where was the initiative for the project coming from
3. where and with what data did you start the development of the dashboards
4. Where there identifiable stages in the development of your uptake of the dashboards
5. Has there been any shifts in focus when you were designing the dashboards
6. did you speak to different people in the organisation/team and did you come against different perspectives.
7. how did your understanding of how best to share your knowledge evolve over the course of your development of the dashboard
8. was there a common dashboard used by several departments? How was this adapted for you to see what you needed to do.
9. Are there any issues that you have with the usability or use of the dashboard, things that were not clear or were confusing or would like to see done to it?
10. What is the next step for you in the development of the dashboards?

Appendix 2 – Interviewees and Observed Participants

Person	Position	Observed/interviewed/worked with
P1	Director Planning	All
P2	Business Intelligence Manager	All
P3	Planning Manager, PLN	All
P4	Planning Manager, PLN	All
P5	Business Intelligence Manager, PLN	Observed/worked with
P6	Director of Learning, Teaching and Student Experience	Observed
P7	EFMS Systems & Space Planning Manager, Estates	Worked with
P8	Systems Administrative Officer, EST (reporting to P7)	Worked with
P9	Head of Student Recruitment Marketing	Interviewed/Observed
P10	Admissions Communication Manager, MKG	Interviewed/Observed
P11	Admissions Communications Manager, MKG	Interview/Observed
P12	Head of Admissions Operations & Visa Compliance	Interviewed/Observed
P13	PV-C, Dean of School, EIS	Interviewed
P14	Head of Library and Learner Development & Deputy Director, LRS	Interviewed
P15	Helpdesk Support Analyst, LRS	Interviewed
P16	Head, Research & Knowledge Transfer Office, MURO	Interviewed

Appendix 3 – Notes

¹ “We define knowledge visualization (in contrast to the mostly data-driven information visualization field) as follows: Knowledge visualization designates all (interactive) graphic means that can be used to develop or convey insights, experiences, methods, or skills. This definition implies that the realm of knowledge visualization is not limited to computer-based images and that the main purpose of knowledge visualization is to support the (inherently social) processes of creating and sharing knowledge with others.” (Eppler 2011)