Design with data:

Practising exploratory inquiring on data visualisation

Graduation project report by **Vignesh Balakrishnan**

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Practising exploratory inquiring on data visualisation

by **Vignesh Balakrishnan**
for the graduation of MSc. in Strategic Product Design

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TU Delft X Ford

Acknowledgements

Dear reader,

This is probably the only piece in this report that did not go through several rounds of refinement before I'm convinced it is good enough. I can't possibly go wrong in sharing my feelings and gratitude.

It wasn't the most logical step for me, a mechanical engineer, to pursue higher education in Strategic Product Design. Not even in my wildest dream had I imagined getting an admission from the mighty TU Delft, let alone graduating from Ford for a 'research into design' project. An adventurous, bumpy, eventful, and rewarding journey of my master's is coming to an end. At this moment, I want to take this space to talk my mind out and offer my gratitude to the many kind people without whom this graduation wouldn't have been possible.

Thanks to my mentors Milene, Senthil, and Nicole. Your attentive and critical feedback inspired and kept me motivated throughout the journey. Thank you for being kind, understanding, and supportive, especially when things were not really going my way. Thank you for your patience and sincere efforts in providing feedback on the numerous versions of the report.

Thank you Paati, Appa, Amma, and Anna. The kindness and good values you teach me are the reason I am where I am today. Thanks to my other family. Swati, Rahul, Shuks, Sidarth, Areef, Santosh, and RV.

Moving to a new country and starting a new life wasn't easy, especially during the pandemic. Srinaath, Naga, UT, Ale, Amal, Akmal, Ren, Jojo, Margo, Akari, Douwe, Betsie, Alina, Robin, Bhavika, Joost, and Laura, thanks for making me feel less lonely and for helping me build a second home. Thank you for accepting me for who I am. Thanks for believing in me when even I found it very difficult to do so. I am extremely grateful for all your kindness.

Last but not least, I want to thank myself. I want to thank myself for not giving up.

Abstract

Intending to implement a data-enabled design approach to use this data in their creative design process, Ford established a research collaboration with the faculty of Industrial Design Engineering at the Delft University of Technology. As part of the collaboration, several lines of research were carried out, like data strategy, data visualisation, and early prototyping in the form of graduation projects. In one such work, Mellado Cruz identified that exploratory inquiring as a means to derive insights from data visualisations has great potential in supporting the creative design process. With her empirical studies, she could generate theoretical knowledge about this process; however, bridging work was needed to convert this knowledge into a practical and actionable outcome.

In this project, I address the research question, "How can exploratory inquiring on data visualisation be operationalised in the Ford design team to support their creative design process? ". I begin the process with a phase of immersion into theory and context- using published literature about exploratory data analysis, data visualisation, creativity, and design theory to obtain theoretical understanding and the thesis reports of past graduation projects. At the end of this phase, I identify three potential opportunities that can aid in implementing exploratory inquiring in Ford design teams. One of the opportunities- to conceptualise exploratory inquiring as a collaborative design method was identified to be the most feasible in terms of the scope of the project, practical and desirable for the Ford design teams. A preliminary concept method was developed based on the learnings from the literature in line with this direction. This was iteratively prototyped, tested and refined for three cycles in the design iterations phase. The version at the end of the third cycle was used to create the final deliverable- a toolkit consisting of an information booklet that helps in circulating the procedural knowledge of the method within the team to create awareness and canvasses that support the execution of the method. In the last parts of this report, I provide recommendations for future studies to tackle the limitations I faced in this project and possibly inspire new works in the area of data-enabled design.

Table of Contents

1 Prelude

1.1 Introduction

A new generation of smart vehicles enabled by complex interconnectivity opens possibilities for innovative user experiences. The interconnected nature of these products, services, and ecosystems generates an astounding amount of data every second. Research and development in technology and fundamental sciences have made it possible to efficiently collect, manage and process data on a much larger scale. It presents a huge opportunity for designers to leverage this resource and drive innovation across domains. In addition to global trends, there is a shift of mindset within the company- Ford from technical product development to human-centred smart mobility (Ford Media, 2020). Both these trends have resulted in cars having smart systems enabled by various sensors and actuators. They not only act as tools to provide real-time smart solutions but could potentially help learn more about how users use their vehicles to identify opportunities for improvements and innovation.

Design and especially human-centred design is centred around users, with the purpose of advocating and responsibly addressing their needs with novel interventions. It becomes paramount for designers to accurately represent the users, the context, and their interaction to understand their needs and scope for innovation. Data helps to bridge this gap, bringing designers closer to the life of users by capturing the actions and interactions in context. Designers historically have employed qualitative research methods like in-depth interviews, ethnography, cultural probes (Gaver et al., 1999), and context mapping (Sanders & Stappers, 2012) to gather data throughout their design process. These studies usually give rise to what is called 'thick' data (Bornakke & Due, 2018), attributed to a rich and detailed account of the context in which the behaviour occurs (Geertz, 1977). Over the years, designers have refined these methods and have preferred to use them in regular practice due to the richness in contextual complexity in such data, which enables critical reflection on how and why people did what they did (Bornakke & Due, 2018).

Although the use of quantitative data is not widespread in design practice, approaches like data-driven design (King et al., 2017) pave the path toward leveraging this emerging material in the design process. One example of a method emerging from data-driven design is

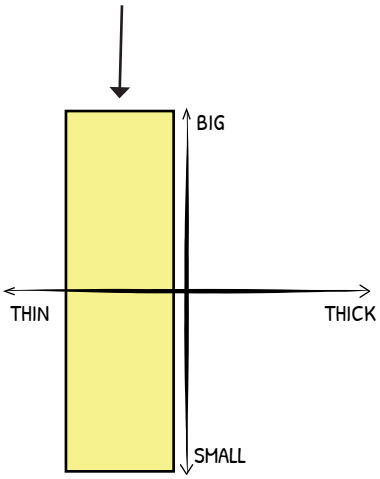


Figure 1: Data axes

Data axes

Bornakke and Due (2018) classify data based on two dimensions- 'volume' and 'Context'. Volume corresponds to the quantitiry of data points available (small to big), while context distinguishes data based on the contextual complexity (thin- less context to thick- rich in context). This project focuses on the quantitative which belongs in the thin region as shown in Figure 1.

A/B testing- where large quantities of data help to select a desired design option from the available set. However, the impact of data with such methods is limited to the later stages of design, typically used for evaluative purposes. However, quantitative data holds much potential and can be used to know the users and their problems in ways that were previously unexplored. There is an urgent need to investigate ways to incorporate quantitative data into all the phases throughout the design process (Churchill, 2012; Kun, Mulder and Kortuem, 2018). But, there are certain challenges involved, including but not limited to the following:

» **Designers may not be data experts.**

Owing to a large number of data points associated with quantitative data, it requires specific knowledge and skillset to carry out processes that make the data fit for analyses (Davenport et al., 2019; Jung et al., 2019; Kun et al., 2020; Data-Centric Design-Lab, 2020). The steep learning curve is an entry barrier for non-data expert designers to incorporate quantitative data into their workflow.

» **Lack of idiographic insights**

Quantitative data is often a result of aggregating data collected over time or regarding a group of people. While this provides a broad perspective on the live world happenings, obtaining idiographic insights (Salvatore & Valsiner, 2010) from such a vast amount of data becomes difficult. Idiographic refers to details about specific occurrences or experiences which may go unnoticed when data is aggregated.

» **A relatively new area of research**

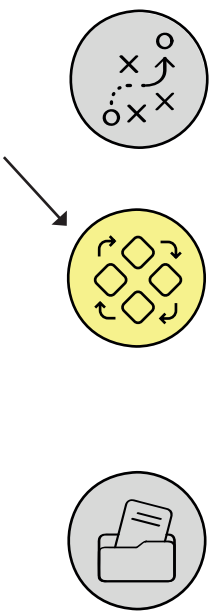
Thick data coming out from qualitative research methods has been applied to gain insights into user needs in support of the design process for decades (Creswell and Clark, 2007). Although the use of quantitative data is not new to the world (it has been widely researched by computer engineers and scientists), adapting these approaches to support the design process is relatively new (Kun, 2020).

New research directions in the line of using quantitative data as a creative design material to inform and inspire the design process- also known as the data-enabled design (Kollenburg and Bogers, 2019) are on the rise (Marti et al., 2016; Bogers et al., 2016). Marti (2016) developed a participative and co-creative approach to using quantitative data for social design, while Bogers et al. (2016) explored the use of interactive prototypes as a vehicle of communication between designers and users in the context of smart system design. Similarly, this project entails research and development of an approach and tools required in using data to identify the needs of the user in the early stage of design in the context of the Ford Smart Vehicle Concept team.

1.2 Context

This project is part of an extended collaboration between the Ford Research & Innovation Centre, Aachen (RIC) and the Faculty of Industrial Design Engineering (IDE), the Delft University of Technology (TUD). The University Research Project (URP) is a 2-year partnership initiated in 2020, determined to advance in data-enabled design approach. The overarching goal of this collaboration is to understand the synergy between data and design, with a focus on building knowledge in (A) Using data in the early stage of Design Thinking approach to understand better the user needs and (B) Using data in the creative process to generate new ideas/service opportunities. Thus far, the URP has resulted in several graduation projects, research projects and university course projects over the period in following three key areas:

I had a personal inclination towards learning about design theory and methodology and was motivated to dive deep into designing design methods, which was one of the reasons for me to get involved with the URP. This project is one such work that aims to support data-enabled design by researching methodologies and developing tools to apply them (as highlighted in Figure 2); other projects that were previously done in this area as part of URP are discussed later in this section.



» **Data Strategy**
Identifying sources of data interesting for designers
Which data helps better understand the user and their context?

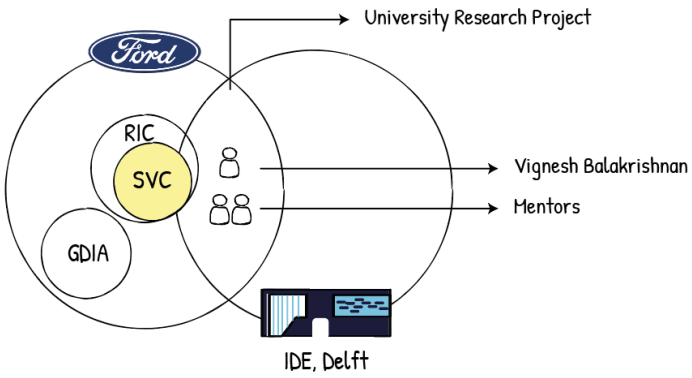
» **Methodology**
Developing knowledge of processes and approaches to effectively leverage data for design.
How can designers incorporate quantitative data into the design process?

» **Application**
Projects where data is used as a material to design with, that is an integral part of the solution.
What new products or services might we offer leveraging the value of data?

Figure 2: Different types of projects carried out as part of URP

1.2.1 Stakeholders

There are multiple stakeholders who play an important role in this project and URP. These include people directly involved in this project (either researching or mentoring) and employees of Ford who carry out the data and design activities within the company.



Research & Innovation Centre, Aachen (RIC)

Established initially to pursue technical advancements and innovation in engineering, RIC Aachen, Germany- the solitary research centre for Ford in Europe- has extended its operation to accelerate disruptive innovation in connectivity, smart mobility, and automated driving. The RIC Aachen is part of the global Ford internal organisation- Research and Advanced Engineering (R&A).

Smart Vehicle Concepts team (Design team)

The Smart Vehicle Concepts (SVC) is a multidisciplinary team of researchers and engineers across domains like innovation management, marketing, and human-centred design, among others and is responsible for designing innovative mobility concepts. They are part of the RIC and employ design thinking to deliver solutions with a near (5 years) and far (10 years) impact.

Global Data, Information and Analytics (GDIA)

Consisting of data scientists and engineers, the department executes data-related queries like setting up data collection, analysis, and visualisation. The SVC team collaborate with GDIA on a need basis, primarily with definitive requests for a specific requirement in a project as opposed to explorative studies.

Mentors

» Nicole Eikelenberg is a Research Engineer at the SVC team, RIC Aachen. She is an IDE alumnus, leading the URP from Ford side and is one of the mentors of this graduation project.

» Milene Guerreiro Gonçalves is an Assistant Professor of Creativity in Product and Service Design at TUD and she leads the URP from TUD side. She is part of the Connected Creativity Lab (CC Lab), established to explore the transdisciplinary value of creativity in innovation and is the chair of this graduation project.

» Senthil Chandrasegaran is an Assistant Professor at the TUD who specialises in Design Theory, Human-Computer Interaction, and Information Visualisation. He is part of the Designing Intelligence Lab (DI_Lab), working on developing tools and methods to foster creative collaboration between artificial and human intelligence.

1.2.2 Past works

As discussed earlier, a cohort of master students from Integrated Product Design, Strategic Product Design, and Design for Interaction at TUD undertook graduation projects as part of the URP on various topics on data-enabled design. The previous projects done in the methodology area as part of the URP sent the first blocks of knowledge in supporting data-enabled by developing novel design processes and toolkits. These projects are briefly discussed below to provide you with an idea of the topics that were researched prior to this project and to better understand the knowledge gap that I am trying to fill with my work. In addition, I introduce these pieces to provide context to the conclusion at the end of this report, where I talk about how the outcome of this project will co-exist with these other works (Chapter 7).

» With the goal of representing quantitative data in a way that stimulates creativity, Spalburg (2021) explored the direction of data physicalisation. Based on the premise that getting hands-on and reflecting on the datapoints enhances creative thinking, she developed a data immersion toolkit: Concreate, consisting of an instruction guide, a physicalisation tool, and a set of reflection cards to be used during creative sessions.

» Hao (2021) examined the space of contextualising big data by combining it with insights from thick data. She went on to develop a toolbox to facilitate the ideation sessions using several creative techniques keeping data at the centre as source of inspiration.

» Ho (2022) also worked on contextualising big-thin data to support the early stage of design. He took the direction of experience prototyping- that is, to understand, exlplore, and communicate what it might be like to engage in the scenario of big data, and developed a tool to practice the same.

» Mellado Cruz (2021) investigated the role of data visualisation in supporting data-enabled design projects, specifically the use of exploratory inquiring on data visualisation to generate insights from thin data.

1.3 Focus

The goal of the URP is not limited to developing theoretical knowledge on data-enabled design methodology but also to delivering practical outcomes that impacts and improcves the way of working in the Ford teams. The URP leaders identified the project 'Exploratory Inquiring on Data Visualisation' (Mellado Cruz, 2021) to be interesting and promising as the proposed concept resonated with the Design Thinking approach currently followed by the SVC team. There was a keen interest among the URP leaders to pursue the work of Mellado Cruz (2021) further and advance in this topic towards an actionable outcome that impacts the Ford team's design practice. This was the starting point of this project that I set to carry out by framing the following research question.

Research Question

How can exploratory inquiring on data visualisation be operationalised in the Ford design team to support their creative design process?

Exploratory inquiring on data visualisation

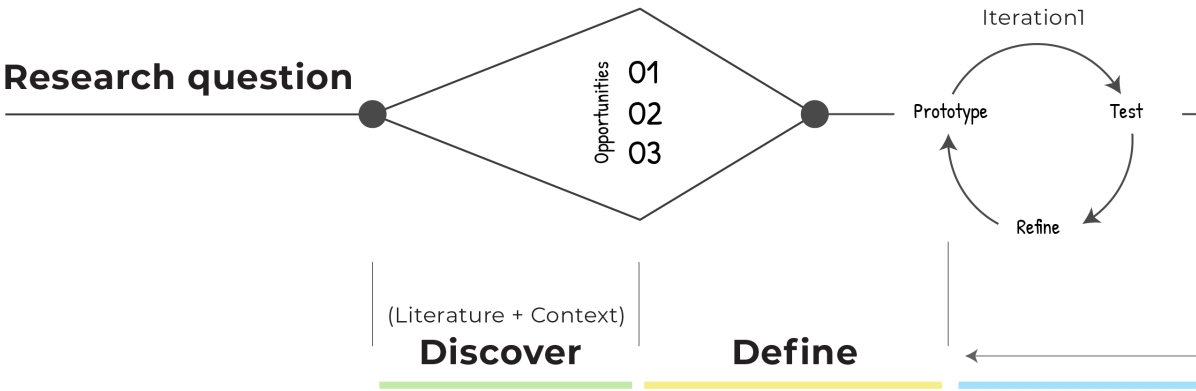
Mellado Cruz (2021) investigated the role of data visualisation in supporting data-enabled design projects, specifically the use of exploratory inquiring on data visualisation to generate insights from thin data. In simpler words, exploratory inquiring on data visualisation refers to the technique of asking questions, as a means to derive insights from the data visualisation in support of the creative design process. She conducted empirical studies to observe and document questions arising from inquiring on static visualisations like scatter plots and histograms and analysed them based on established question taxonomies (Eris, 2004). When these questions were analysed, she found that the questions emerging from the visualisation were a mixture of different classes of questions; and that certain types of questions trigger specific actions, like exploration, ideation, or even prototyping. However, there is a gap to be addressed in translating the theoretical knowledge of the process to a solution that is practical and actionable. The process needs further detailing, accounting for the capabilities and resources available to the design team and practical challenges at the time of executing the process.

Operationalisation

Operationalisation is a multi-dimensional concept. From a theoretical standpoint, the term is used to describe translating abstract research concepts into concrete, measurable variables (Weaver, 2015). But in this project, I refer to the practical definition of putting exploratory inquiring on data visualisation into use or implementing the technique within the organisational context.

1.4 Approach

The approach to tackling the research question consisted of several design and research activities. I adopt elements of design thinking to guide the process, such as involving the users- designers at Ford SVC throughout the project (Brown, 2009; Martin, 2010) and iteratively refining and developing the solution in subsequent studies. (Rylander, 2009). The project proceedings are divided into phases: Discover, Design, and Deliver.



Discover

The first phase of this project corresponds to immersion into the theory with the help of published literature and into Fords team in the context research based on digested insights from past graduation projects. The goal of context research is to obtain insights into Ford's current data and design processes concerning the SVC and GDIA teams. In the literature research, I review research papers on exploratory data analysis, data visualisation, design theory, and creativity in relation to the research question. The insights from this phase are presented in Chapters 2 and 3.

Define

Based on the insights from the Discover phase, three opportunities were identified, out of which conceptualising 'exploratory inquiring on data visualisation' as a design method was chosen to progress with (Chapter 4). A brief exploration into the literature on design methods were carried out, followed by formulating specific requirements that the concept must meet.

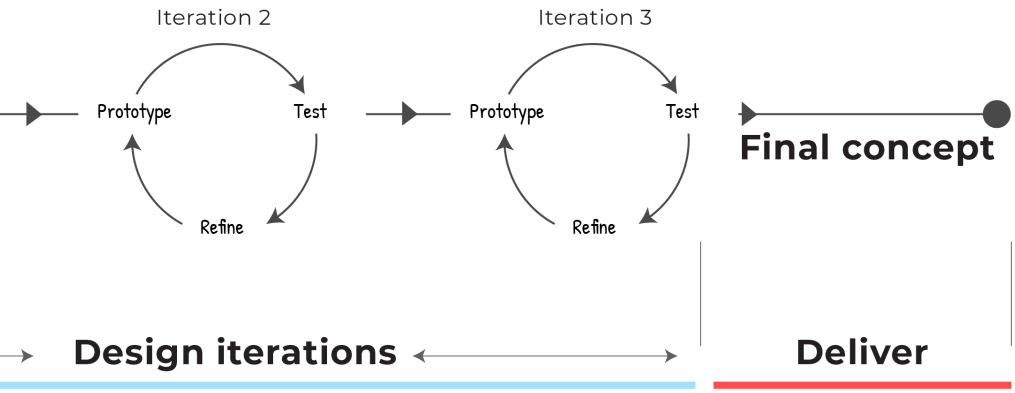


Figure 4: General overview of the phases and activities of the project.

Design

A preliminary concept method was conceived and iteratively prototyped and tested using three formative studies. Based on the learnings from each of the studies, the concept was improved by reflecting on the challenges, comparing them with relevant literature, and modifying the procedure of subsequent iterations. The details of these studies and outcomes are discussed in Chapter 5.

Deliver

The version of the method procedure at the end of the Design phase is used to build the final deliverable. The final deliverable, along with the it's implications to the company are discussed in final chapter of this report. In addition, an extensive list of recommendations is also included in this chapter to inspire future research in this area.

2 Context Research

This chapter aims to provide an understanding of the current processes, challenges and opportunities concerning design and data practices at the SVC team. The information gathered from several sources (A, B, and C) is assimilated and presented in this chapter.

A **Insights from previous graduation projects**
As discussed in Section 1.2, several students who previously worked on this URP have conducted several studies through interviews and observations to gather insights into this area. The primary source of information for this chapter is the digested insights from the thesis reports of their graduation reports.

B **Regular weekly meeting with the company mentor- Nicole Eikelenberg.**

C **Interviews N=2**
In addition, I conducted two semi-structured interviews, each lasting about 1 hour, with members of the SVC team (P1, P2). The sampling was done based on their expertise in design thinking and availability. The goal of this interview study is (A) To empathise and get to know the members of the SVC and their attitude towards Design Thinking (B) To find answers for some pieces I found missing from the past studies.

- **Could you describe your most recent project, the approach, and the steps involved?**
- **What were the design methods and tools used for user research?**
- **What is your strategy to generate insights, when do you stop exploration and move on to the next phase?**

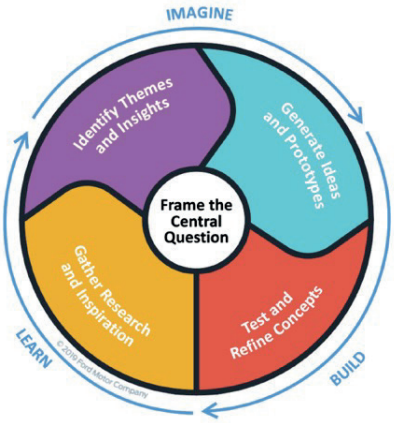
2.1 Introduction

The focus of this project is to support the working Smart Vehicles Concept Team located in the Ford RIC Aachen. They are an important stakeholder to this project and play a vital role in carrying out data-enabled design operations with the company. The core objective of this team is to design and develop innovative mobility concepts with a medium-long term impact. They take up several types of projects, but common to all is identifying innovation opportunities and coming up with novel solutions in the form of new products and/or services to enhance the user experience of Ford vehicles. The new product development (NPD) process is based on a series of development stages that spans idea generation and launching the solution in the marketplace. These stages are broadly classified as concept development, product development, and commercialisation; each has its objectives and is intertwined with corresponding evaluation or testing goals (Tzokas et al., 2004) regarding the desirability, viability, and feasibility of the solution.

The SVC team operates in the early stage of concept development which is characterised by complex and open problems, where it is essential to explore, identify and define the problem before attempting to solve and evaluate it. (Section 3.2). One striking difference between the concept development stage and other stages is that for the latter, there is usually a well-defined problem, and the challenge would be to figure out the best way to solve them. But in the early stage of concept development, it is crucial to understand the users and their context, and identify the right problem to solve. To tackle this, the team employs Design Thinking approach (Figure x.x) to understand the users and their needs to frame the problem to be solved. The human-centred mindset derived from the DT approach drives all operations and initiatives within the team, and they strive to involve users at every stage of the design process, strengthening the feedback loop. As the team members are experienced researchers, they embody these principles in their regular workflow and do not actively refer to the DT framework to guide their projects. Spalburg (2021) observed a similar attitude towards design thinking within the SVC team. Each project takes shape in unique ways, and they adapt their process based on what the situation demands. However, the framework helps to keep a check and communicate the project's progress with colleagues and managers.

> *"So, in general, we are using the design thinking methodology. But I wouldn't really say that this is guiding me personally." -P1*

Ford x IDEO Design thinking cycle



In 2017 to implement a human-centred approach to problem-solving in the organisation, Ford collaborated with IDEO to give birth to the Ford Design Thinking cycle. This framework acts as a guideline for employees/teams following a non-linear and iterative process of finding and solving problems keeping users at the centre of every step.

The model consists of 5 parts: Central Question and 4 Design phases.

Central Question:
Describes the motivation of the project and the problem to be solved.

Gather research and inspiration:
Improve the understanding of the problem area by analysis.

Identify themes and insights:
Make sense of collected materials, reveal patterns, and gain insights.

Generate ideas and prototypes:
Explore the possibilities in solving the identified problem and prototype early to realise concepts.

Test and refine concepts:
Evaluate design concepts and verify the relevance of the proposed solution at ground level.

Figure 5: Ford x IDEO Design Thinking Cycle

2.2 Design perspective

As we saw previously, the SVC team is involved in the concept development stage. In this space, they usually carry out several projects simultaneously and the projects they take up often originate from one of their previous assignments or elsewhere within the company. All of their projects start with defining the central question that acts as an anchor around which the project evolves. At the end of a project, the outcome is delivered in the form of mid/high-fidelity concept(s), after testing for desirability and feasibility, which is either handed off to the internal customers or championed within their team for further technical developments and viability studies.

The steps taken while tackling each central question vary widely depending on the project. While some projects are short-term, long-term projects take several iterations that span over months or even years, depending on the project's complexity. Each project is typically handled by one or two members of the SVC team who take the role of project owners. As a project owner, they are responsible for taking initiatives and the overall progress of the project. The project owner carries out their work not just by themselves but are supported by other members of the SVC and other teams within Ford at specific moments if needed. For example, if the project demands data-related processes, the project owner gets in touch with the GDIA team to communicate and seek assistance when required.

2.2.1 Project Journey

As discussed in the introduction, each project takes shape in unique ways and demands the designer to adapt their approach in handling the assignment. Mellado Cruz (2021) identified four categories of projects that are typically executed within the team, namely, Explorative, Discovery, Technological Development, and New Product Development (a combination of the first three) (Mellado Cruz, 2021).

- Explorative: To identify opportunities for new products or services.
- Discovery: To determine the feasibility of a specific idea.
- Technology Development: To innovate on technical aspects required for the novel solution.
- Product Development: To create a product or improve existing ones.

Keeping that in mind, I map out a representative journey of one of the projects carried out in a timeline by the Ford project owners based on the insights gathered from my interviews with them (Figure).. A typical project begins with a high-level, open-ended central question. For example: "How to enhance the Ford in-car experience for the generation-z customers?". Then, in the first phase, which I name it the open exploration, several

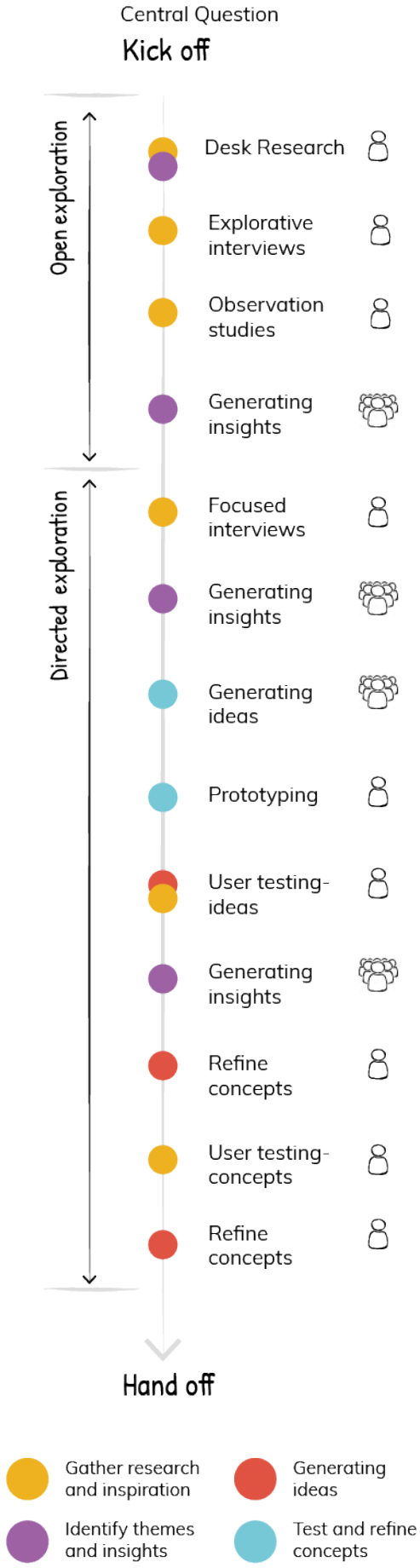


Figure 6: Representative journey of one of the projects carried out in the SVC team. Some of the activities are executed several times iteratively, however, for the sake of simplicity, they are mentioned only once in the figure.

design activities are carried out such as desk research, user interviews, and observation to gather insights and inspiration. The goal of this phase is to identfy potential opportunities to explore. After a series of iteration, and once the problem is well defined, the project owner enters the directed exploration stage. Here, the project owner carry out design activities with a more scoped down area of search, where several iterations are carried out to further refine the problem and solution space (More on this in section 3.2). While the project owners execute most activities of the project by themselves, for example, conducting studies, gathering data, and building prototypes, there are two instances where they involve their colleagues from the SVC team (also from other teams if required) in their project. For generating insights to from the collected research data and ideas to the proposed problem statement, the project owners collaborate with their peers by hosting creative sessions. Details about creative sessions at the SVC team is explained in the following section.

2.2.2 Creative Sessions

Creative sessions are essential throughout the SVC team's design process. As SVC comprises of individuals from varied enginnering backgrounds, such creative sessions help bring in the various perspectives and expertise available in the team, leading to a rich and fruitful outcome. These sessions are hosted and

facilitated by the project owner, and she/he prepares the material to be shared with the participants during the session.. The material taken into the session is based on the desk and qualitative research studies done prior to the session with the aim of providing information on the context of the project to the participants (Spalburg, 2021). These materials currently include audio, videos, pictures, and self-made materials like user explanations or storyboards, based on the qualitative research studies like interviews and field observations. They are shared with the participants in the form of slideshows at the beginning of the session with the goal of catching up the resource group with the information collected so far in the project. The sessions generally happen in-person, where participants work with sticky notes and whiteboards at the office location. But due to the recent shift to an online mode of working caused by the pandemic, they adapted these sessions to an

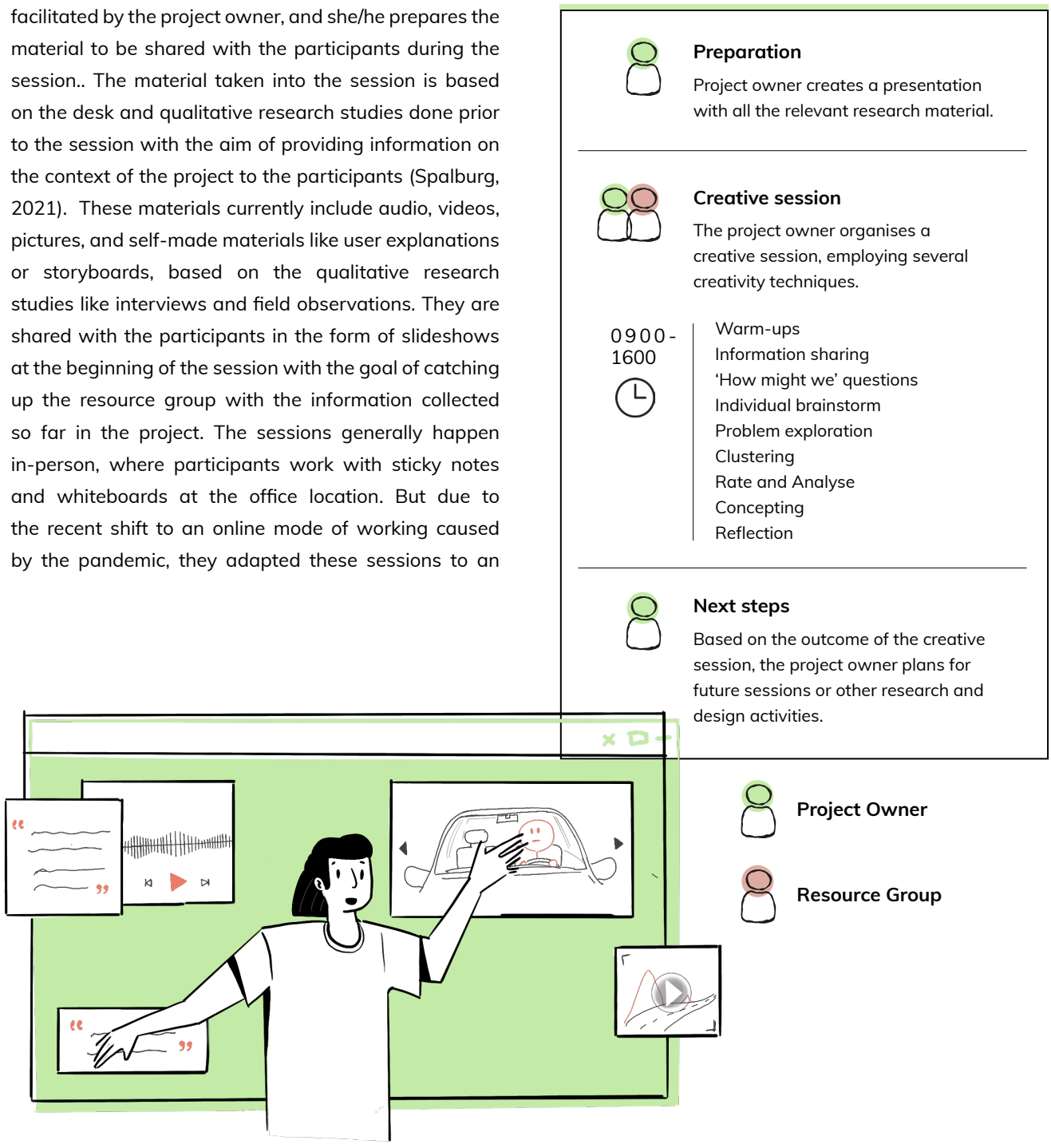


Figure 7: Illustration showing the different types of information shared in a typical creative session at SVC (top) and the different activities that take place as part of the session itself (right).

online setting, using tools like (WebEx- for web calling and Bluescape- online whiteboard). Although working online provides convenience, the members collectively agree that working in person, especially for creative sessions, is more productive.

Some of the insightful comments from the interview study are mentioned below.

» They adopt a convivial yet structured way of generating insights.

"One insight or observation, one post-it. Then we put everything on the wall, think about how to cluster different things, and then we have clusters. We name the clusters. Then extract the summary inside every cluster, which then opens up opportunity areas." P1

» A design engineer from the SVC team replied with the following when asked why he prefers to employ qualitative research methods over quantitative methods. He pointed out the context rich nature of the data collected from qualitative studies is useful to comminicate the full picture about the problem identified.

"but I can bring a story. I can tell you directly to have a look. I was here with the craftsmen (the target group of one of his past projects), I was working with him, and have a look what he showed me; that's an obvious problem."P2

» It is important to know when to stop with research and enter into the ideation and product development. Approval from sponsors and managers is essential for progressing further in the project.

"You always have to convince your managers. You always have to convince sponsors and champions to continue with the project."P2

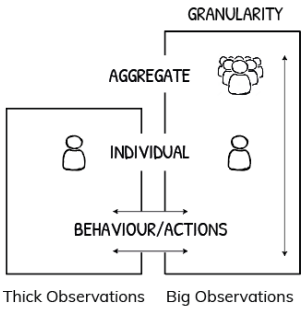


Figure 8: Comparison between attributes of big and thick observations (Bornakke & Due, 2018).

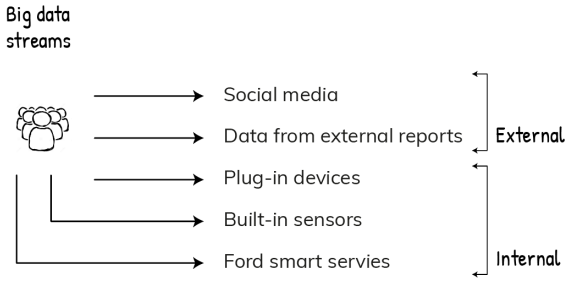


Figure 9: The different data sources available/ accesible for the SVC team to explore.

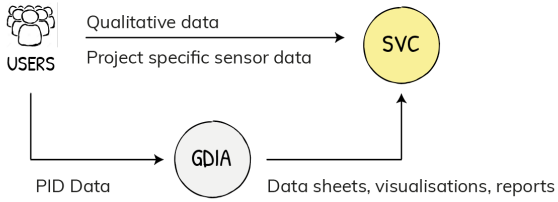


Figure 10: When handling larger datasets, the SVC team relies on GDIA for handling data processes.

2.3 Data Perspective

The SVC team currently rely primarily on qualitative data to understand the users and their context in both the open and directed exploration. These include data from in-depth interviews, field observations, co-creation sessions, and observations from social media like YouTube, Twitter, and Quora. The use of quantitative data is limited to the verification of decisions and confirming the insights from qualitative data, typically later in the design process. However, there is a wide spectrum of big-thin data accessible and available to the team that can be potentially used; for example, open datasets from the web, data from built-in systems, PID (Plug-In devices), and Ford smart services (Ford Pass and Ford Sync). These data can provide an individual and aggregated level of insights into user behaviour by measuring various real-life actions and allow for granular observations over a large population (Bornakke & Due, 2018). They aspire to utilise these data better in their user research to gain insights that inform and inspire their creative design process.

Like most large organisations, Ford has a dedicated team of data engineers, data analysts and data scientists in GDIA team who are specialists in handling data-related operations like gathering, managing, and analysing quantitative data. The SVC team internally collaborate with the GDIA team if they require data expertise in supporting their design activity espescially when it comes to handling big data. This can be either to get access to already collected data available with the GDIA or to set up a project-specific data collection. The GDIA maintain a repository of data that has been previously collected by the company using big data tools like Hadoop (Chang, 2021). This collection comprises of raw data and data tables (Section 3.3) of the data collected from one of the many sources discussed before. For both, setting up a new data collection and

to use already collected data, they must undergo a rigorous procedure complying with GDPR privacy regulations. The General Data Protection Regulation (GDPR) set up by the European Union (EU) lay down rules relating to protection and privacy ensures that organisations collect, store and process personal data responsibly. To comply with the gDPr regulations, Ford has implemented strict policies to confirm the judicious use of personal data within the company. This means that getting access to the personal data takes significant time and effort which hinders the fast-paced and iterative nature of the design projects.

In addition to the general challenges discussed in Section 1.1, several challenges are specific to the SVC team while incorporating quantitative data into the design process in the next page.

2.3.1 Key Challenges

» **Access to data engineers and lead time.**

As like many other design teams, the SVC team does not have data engineers inside their team. They must must rely on external help (within Ford) for setting up new big data collection or any data related assistance. The GDIA (or any other team providing the data) needs to follow a rigorous procedure complying with the GDPR privacy regulations before the data can be used, which increases the lead time. (time from deciding to use the data to actually using the data.

» **Differences in mindset**

The GDIA predominantly works with confirmatory requests, which usually have a testable hypotheses that could be either proven/disproven with data deductively. However, SVC wants to use data for explorative purposes, which oftentimes means performing analysis without a specific pre-determined results in mind. This requires a designerly mindset or abductive way of thinking (Section 3.2). This difference in mindsets between the teams involved is one of the key challenges in executing data-enabled design as identified by Jansen (2021).

» **Overwhelming amount of data and datasets.**

While designing with data, the amount of information available increases exponentially, as well as its complexity. The project owner must select the ones to use carefully from all the available and 'possible to collect' datasets that will guide the project direction. The amount of data contained in these datasets can become daunting and usually require programming expertise to carry out the processes.

» **Data privacy GDPR regulations**

As discussed earlier, the use of user data is subject to strict GDPR privacy regulations, especially with Personal Identifiable data (PID). It is not possible to use the data for any other purpose other than its intended use without furnishing a valid reason that requires approval. Since, for exploration, there are no pre-determined results before looking at the data, it makes it difficult for the designers to get access to personal data for exploration.

It is not allowed to trace back to the user from whom the data was generated (Hao, 2021), dismissing the possibility of follow-up qualitative studies with the same user.

» **Lack of process and methods incorporating data in design.**

As mentioned previously, the SVC team is competent in handling certain levels of filtered data by themselves. However, not having standard protocols or methods to rely on how to use quantitative data for design process makes it difficult to take initiative.

» **Perceived value vs Effort.**

There is scepticism around investing time and effort in exploring a relatively new source of information like big data to explore design problems which don't have a proven track record of being valuable and practical.

Takeaways

The SVC is involved in the early stage of product development, that is, the conceptual design. They employ a human-centred design approach to explore, identify, and define the problems of the user before ideating, prototyping, and testing iteratively.

The team is comprised of researchers and engineers from various backgrounds who practice design thinking approach in their workflow. They are not data experts; however, they are capable of handling filtered and structured data to create required visualisations.

Creative sessions are an important part of their workflow. The project owner typically hosts such sessions where they takes in data collected through research activities as input material and also acts as a facilitator guiding the participants through the creative activities.

The team currently utilises qualitative methods like interviews and observations in their design process. But there is a huge interest and motivation to leverage quantitative data (big-thin) to uncover insights on user needs to inform and inspire their creative design process.

3 Literature Research

The objective of the project is to investigate “How can explorative inquiring on data visualisation be operationalised within the SVC team to support their creative design process? ”. Literature from the fields of design theory, creativity, data visualisation, and design methods were reviewed to get acquainted with the body of knowledge created by previous research works done in this area.

The insights from literature that were relevant to the direction in which the project developed are presented in the following sections. In addition, the chapter contains several ‘Reflection boxes’ that contain details of the ideas and reflections that emerged during the Discover phase. These directions were found to be interesting and briefly explored especially in the early stage of the project. Due to limitations in scoping, resources, and the author’s expertise, they were not developed further. They can be seen as areas of interest that can possibly be pursued in the future.

REFLECTION BOXES !?

3.1 Exploratory Data Analysis, Data Visualisation, and inquiring.

In this section, I first define the concept of exploratory data analysis (EDA) and the principles involved in practising EDA, followed by the different processes involved in getting the data ready for analysis. This part of the literature aimed at understanding the elements that ensure fruitful exploration (according to past studies) and the level of data expertise required to conduct an exploratory data analysis.

3.1.1 What is exploratory data analysis?

There are two approaches to data analysis: Exploratory Data Analysis and Confirmatory Data Analysis. Originally formalised by American mathematician John Tukey, Exploratory Data Analysis (EDA) is 'an attitude and a state of flexibility, a detective work designed to reveal the structure or patterns in the data' (Tukey, 1980). With recent advancements in the data science field, this notion was revisited by Alspaugh et al. (2009), who define exploration as flexible, open-ended information analysis, that doesn't always have a precisely stated goal. On the contrary, Confirmatory Data Analysis (CDA) corresponds to statistical techniques performed to test specific hypotheses regarding the data. This approach is often used when the analyst has a clear idea of what they expect to find in the data and is used to confirm or reject these expectations.

The core purpose of EDA is to get acquainted with the data and to answer the question "What is going on here" in the available dataset (Behrens, 1997). It is characterised by being opportunistic, a process where the actions are driven as a reaction to the presented data in a bottom-up fashion guided by a higher-level goal of finding something new (Alspaugh et al., 2009), that is, to discover patterns and relationships in the data. Due to the very nature of EDA being flexible and opportunistic, an appropriate procedure or sequence of steps to carry out the analysis cannot be pre-determined, as it varies based on purpose, use, and situational needs. Nevertheless, researchers have made attempts to study how analysts typically carry out EDA (Behrens, 1997; Morgenthaler, 2009; Batch & Elmqvist, 2018). Based on these works, I derive the following heuristics that can aid the practice of EDA.

Mindful of the context:
Having a good understanding of context is crucial for any analysis. Even more so when performing EDA, as various factors could influence the analysis result.

The use of graphics/visualisation:
As EDA aims to develop a richer understanding of data by identifying connections and patterns, visualising the data is often the first step in any data analysis.

Univariate summaries:
Visualising variables individually helps to get a grasp of the range and nature of the distribution.

Develop insights in an iterative process:
In EDA, informal inferences and hypotheses are made by viewing data from multiple perspectives, which is further strengthened by iterative data analysis.

Residual Analysis:
In simpler terms, it is crucial to focus more on the outliers or the things the model could not explain.

In the next section, I will explain in detail why data visualisation plays a crucial role in exploratory data analysis, followed by the different steps involved in visualising the data.

3.1.2 Data Visualisation and exploratory data analysis

Data Visualisation (also called Information Visualisation or InfoVis.) refers to using a computer-supported visual representation of data. Owing to the large amount of data points associated with quantitative data and the limited short-term storage and processing capacity of human minds (Miller, 1956), it becomes difficult for the human mind to comprehend, process, and remember effectively. Visually representing data amplifies human cognition, thus increasing memory and processing capabilities (Card et al., 1998), enabling navigation of vast data quickly to discover insights (Batch and Elmqvist, 2018).

Data visualisation is useful not just to represent the data as a means to communicate the results of analysis but also valuable as a means to conduct the analysis to explore and generate meaningful insights (Tukey, 1980). Escpecially for Exploratory data analysis, As the core of EDA is to find interesting patterns, connections and relations in the data, visualisation plays an important role in executing EDA. Visualisation, is however, not a straightforward or simplistic process. It involves a series of steps in which is further explained in the next section.

3.1.3 Data processes involved in visualising data

Several models of the information visualisation process describe the steps involved in configuring and using visualisation to gain insights. The 'reference model for visualisation' (Card et al., 1999) describes how visualisations are created and how the users interpret and interact from a data-oriented perspective. Ward et al. (2004) suggest that 'data gathering' is an essential process that also needs to be considered when thinking about data visualisation as analysis could lead to potential new data collection strategies. Therefore, I use the modified reference model to streamline the discussion around the data visualisation system to compare and discern them.

Data gathering: Data gathering corresponds to the collection and storage of data. Behind every quantitative measure and metric, there are various qualitative judgements and technological limitations (Churchill, 2012). For example, 'What should we measure, why do we need to measure this, what can we measure, how can we best measure it, what is the metric constituted,

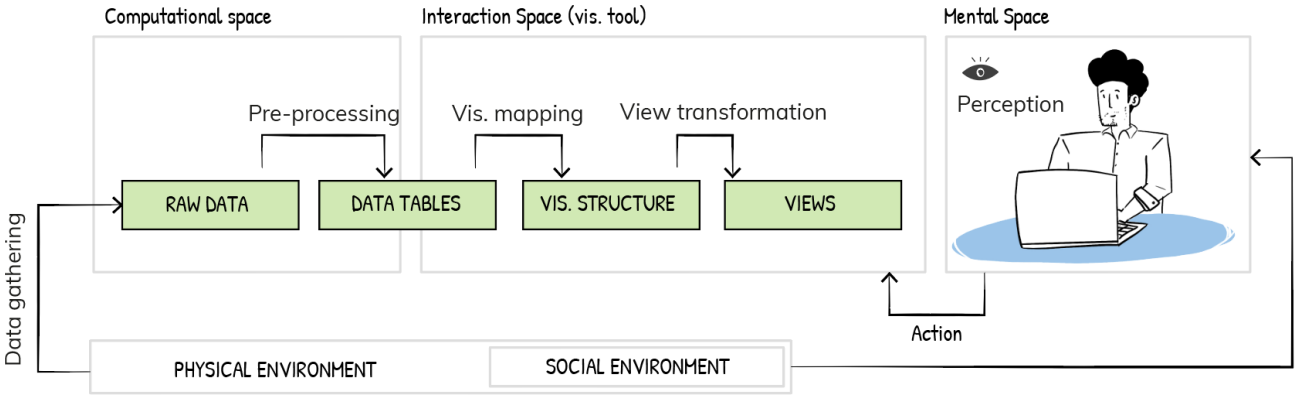


Figure 11: Processes involved in information visualisation inspired by Card et al., (1999) and Ward (2004).

and what does get measured?'. When establishing a new data-collecting strategy, it is critical to consider all the qualitative elements and install a suitable probe to gather data. When using data already collected by an external party, it is important to consider the background information, constraints, context of the measured metrics, and the real-life event the data represents before analysing the dataset.

Pre-processing: The raw data needs to be processed and transformed into data tables in the pre-processing stage (Ward, 2004). Pre-processing of data, also known as data wrangling, consists of complex tasks such as integrating data from multiple sources, cleansing it, and transforming it into structured tables. Such tasks usually require data expertise (Grammel et al., 2010) as they involve several mathematical and computational. However, tools like Alteryx provide a graphical user interface reducing the entry barrier for non-expert users to carry out the task.

Visual Representation (Visual mapping + view specification): In the next stage, the resulting data tables are mapped to visual structures. There are two key factors involved in deciding 'how' to visualise the data; Graphical marks - a geometric element or token that represents a data point, such as a point or a line and the Encoding channel - an attribute controlling the marks' appearance, such as their position, shape, size, or colour (Munzer, 2014). In practice, visualisation experts create novel representations, carefully deciding on the markers and channels based on the data type (nominal, ordinal, discrete or continuous) and the purpose of visualisation from scratch. However, creating such visualisations often requires programming expertise (Heer & Schneiderman, 2012) and is time-consuming.

In the interest of time, effort, and expertise needed to make such visualisations, visualisation tools easily accessible to non-data experts, such as Excel, Tableau, and QlikView, are considered relevant for the scope of this project. These tools are powered by systems that can suggest visualisations based on partial specifications provided by the user. For example, in the case of Tableau, the user can drag and drop data variables onto the shelves. Furthermore, the system suggests possible chart typologies based on the combination of data types selected. Although this limits the creation of novel visualisations, these are preferred due to simplicity, familiarity, and usability benefits.

Recent research in visualisation tools focuses on assisting the analyst in generating the desired visualisations during exploration. For example, Voyager

How might we support designers in the process of setting up new data collection? 

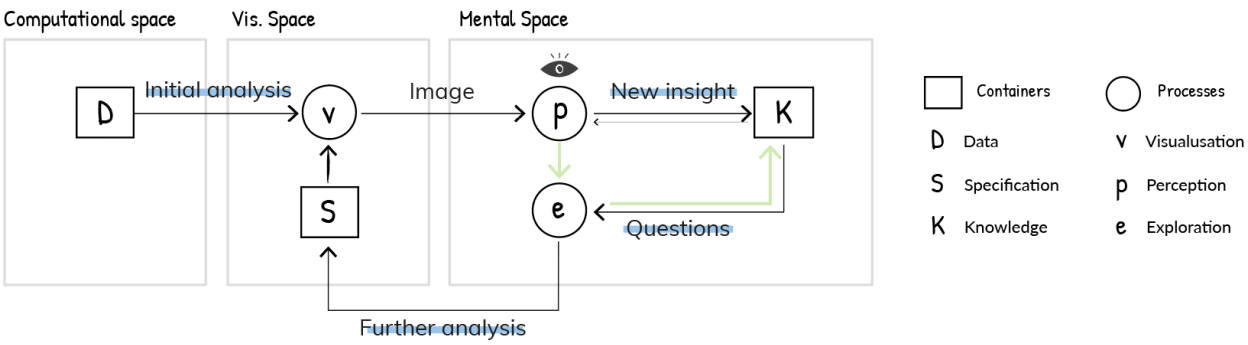
Selecting a suitable dataset or setting up a new data-gathering strategy is a crucial element for the analysis to be productive. As seen in Section 3.3.2, data gathering involves carefully considering several qualitative aspects in addition to technical feasibilities and limitations. As the popular saying with data goes, "garbage in, garbage out" data gathering is a vital step in ensuring a good outcome from exploratory inquiring on data visualisation. Therefore, supporting designers in this process is an interesting space to explore further.

(Wongsuphasawat et al., 2017) provide sensible visualisation suggestions based on none/partial specification, while Eviza, Articulate 2, and Snowy make use of natural language processing (Setlur et al., 2016; Aurisano et al., 2016; Srinivasan & Setlur, 2021) to create new visualisations based on verbal inputs. These tools are in the early stage of development and have not reached mainstream markets yet. Although it is intriguing to consider these tools for this project, as it, in many ways, enhances the experience of visualising the data and makes the process more accessible for novice users, keeping in mind the timeline of the project and organisational requirements, they are considered out of scope.

So far, we examined the processes to be carried out at an external level in creation of visualisations from raw data. In the next section, we will look at the internal (cognitive) processes in deriving meaning from the visualisation.

3.1.3 Cognitive processes involved in deriving insights from visualisation

The mechanism with which data visualisation users seek and obtain insights involves a complex set of cognitive activities, and its depths still need to be better understood. (North, 2006; Reda et al., 2016). However, on the surface level, extracting insights from data involves three functional spaces: computational, interaction (visualisation tool), and mental space (Seidig et al., 2012). Based on previous works (van Wijk, 2005, Keim et al. 2008), Green et al. (2009) proposed a model depicting the cognitive processes involved in extracting knowledge from a data visualisation. As you can see in figure, the data processed by the visualisation system is perceived as an image by the user. The perception system extracts details (knowledge) over time from the visualisation, which leads to further exploration and analysis after being processed in the mental space. Here, the exploration can either manifest as actions that



Original model: (Van Wijk, 2005) Improvements (Green et al., 2005) Explanations (Keim et al., 2008)

Figure 12: The sensemaking process in visual analysis.

modify the visualisation or identify a new insight that furthers the subject's understanding. The modifications to the visualisation could be in view specification-changing the subset of data visualised but maintaining the exact visual representation, or changing the visual representation, maintaining the same data input but altering the visual structure. The model elucidates that obtaining knowledge depends on a combination of the user's perception of the image and the different actions that enable the user to explore and modify the visualisation.

In the modern visualisation tools, this this modification or manipulation can be made in real-time using the interactive features. Interactivity in data visualisation is defined as the ability to manipulate and change the visualisation state directly. (Yi et al., 2007). As interactive visualisations facilitate the dialogue between the user and the visualisation system conveniently, it allows the user to analyse the data much more efficiently.

Concerning the mental space, researchers have pointed out the importance of externalising insights/hypotheses and the need for tools to support this process (Gotz et al., 2006; Shrinivasan & van Wijk, 2008). Externalising insights in the form of questions is beneficial for several reasons. Firstly, "questioning enables us to organise our thinking about what we do not know" (Berger, 2014). Questions reflect a lack of information (Baya, 1996), helping to capture the need for exploration during an analysis. Lastly, questions help express curiosity, which is the motivation to find the missing information. Inquiring or question-asking is not only prevalent with data analysis but also has great importance across domains. The role of questioning and questions in design is discussed in the following section.

3.2.5 Inquiry-based design methods

Questions play a vital role in expressing the inquisitive mindset that is necessary for explorative studies (Nelson and Stolterman, 2014). Design is an information intensive activity (Baya, 1996) and since questions help us to organize thinking about the things we do not know (Berger, 2016), questions play a major role in the design process. In design teams, during peer feedback sessions, designers exchange questions between team members that helps to futher their understanding and build a shared mental model (Cardoso et al., 2014). In design reviews with students, coaches use questions to trigger reflection and learning (Cardoso et al., 2014). In individual work, questions help to reflect during and after the design activity (reflection-in-action and reflection-on-action) to learn and improve the design processes (Schon, 1983).

Inquiry-based design methods have long been used to trigger creativity in design practice . A large number of creativity methods apply questioning either implicitly or explicitly as a mechanism to spark people's imagination and encourage them to think from different perspectives. Some of the methods that explicitly make use of questions to trigger creativity are the 'How To' and 'How Might We' (Heijne and van der Meer, 2019) techniques found in creative facilitation. Here, the resource group (the people participating in a creative session) are deliberately asked to frame questions starting with those phrases as a diverging activity in the problem finding phase. '5W1H', an analytical tool

that encourages designers answer the 5Ws (what, when, where, who, why) and 1H (how) questions when trying to formulate a design problem. Although the use of questions as a tool to foster creativity in design is not new, studies relating to analysing questions that emerge during a design activity are (Eris, 2004)

Building on previous works on taxonomies of question, Eris (2004) developed a model of inquiry-driven design, classifiying and differentiating questions according to their conceptual meaning. In his studies, he observed that certain types of questions relate to a higher design performance in the context of designing physical (tangible) products. He defines two classes of questions, namely, Generative Design Questions (GDQ) and Deep Reasoning Questions (DRQ). GDQs were prevalent in the divergent phases of the design process, helping generate possibilities in the form of ideas and information. DRQs were prevalent in the convergent phases, helping designers critically evaluate the options and move towards a decisive conclusion on the next steps to take. Although Eris's work highlighted the importance of questions in design, studies on taxonomy have not inspired much further research (Aurisicchio et al. 2006) and have not contributed to tool development. There is the awareness that certain classes of questions, when asked during a particular phase, enhance design performance; there is no clear idea of how to encourage asking these questions. It would be valuable to look into this space to support designers in asking better questions when analysing the data visualisation based on the purpose of the analysis and the knowledge that they are trying to generate. In the next section, we will look deeper into the role of knowledge and information in design thinking and the strategies designers adopt in generating this knowledge.

Working in groups vs working individually! !?

In design projects, it is common to collaborate with fellow designers, stakeholders or target users, to obtain a wider perspective. Their collective expertise of various domains (users are considered to be experts of their experiences) contributes to a richer creative outcome. Although collaborative data analysis is not an entirely new concept, data analysis is usually conducted by individual analysts. It would be interesting to find a balance between the two modes of working.

Takeaways

Exploratory Data Analysis or EDA is opportunistic, open-ended information analysis that doesn't require a precisely stated goal, where the actions are driven by insights generated from the data.

Data visualisation is an indisposable tool when carrying out EDA as it helps amplify human cognition when analysing large amounts of information.

The use of data visualisation for explorative analysis involves four high-level processes, namely, data gathering, pre-processing, visual representation, and visual analysis. Data gathering and pre-processing require high levels of data and programming expertise, while visual representation and analysis are accessible for the SVC designers with the help of novice tools.

Interactivity in data visualisation refers to the ability to directly manipulate the state of visualisation. They allow the analyst to act quickly upon the insights and foster deeper and faster exploration.

3.2 Information, Design Thinking, and Creativity

Design Thinking is an important element of SVC teams' operation. Literature from the area was reviewed to understand the fundementals of creativity, role of information in design thinking and how knowledge is generated from data.

3.2.1 Design Thinking

Design thinking is considered an approach to creative problem-solving, particularly when addressing ill-defined or 'wicked' problems (Buchanan, 1992). These can be understood as problems without a clear goal, path, or expected solution. In other words, design thinking specialises in 'what can be instead of 'what that is' (Martin, 2010; Zimmerman et al., 2007). First, however, one must review the current state with a critical lens to understand more about the preferred state to capture the nuances and identify the pain points. This forms the basis for several approaches, including but not limited to the 'what to why' model (Sinek, 2009), Vision in Product (Hekkert & van Dijk, 2016), and the Frame Innovation method (Dorst, 2015).

3.2.2 Co-evolution of problem and solution spaces

In the early stage of the design thinking process, it is critical to interpret the context and identify the problems with sufficient details to generate the most appropriate solutions. However, due to such problems' ill-defined nature, it is impossible to identify and define them precisely in the first go. Hence, designers tend to move back and forth from the problem and solution space in their creative practice, iteratively getting to know the context better and gaining knowledge each time they make a design move (Maher et al., 1996; Dorst & Cross, 2001). This description of the creative design process is known as the co-evolution model (figure).

In essence, the problem and solution space grow in parallel, where the problem-to-be-solved changes with the addition of new knowledge when trying to solve the previous version of the problem. Information triggers co-evolution (Gonçalves & Cash, 2017), and the constant flow of information between these spaces is

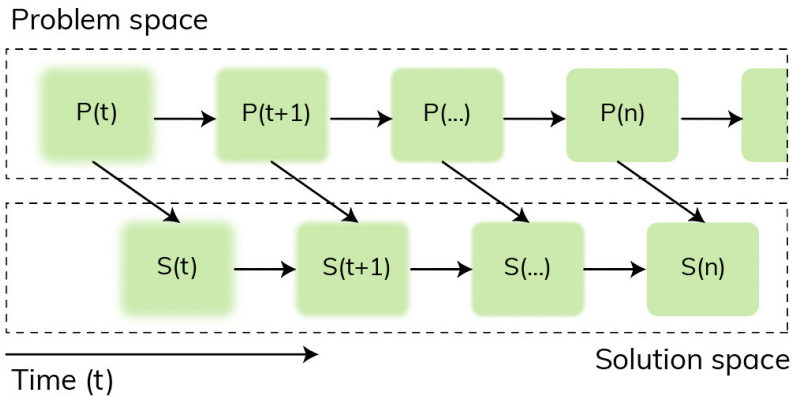


Figure 13: Co-evolution of problem-solution (Dorst & Cross, 2001).

vital for the design process (Dorst, 2011). Information assists designers in multiple ways; it helps manage uncertainty in the innovation process (Jalonen, 2012), helps in the framing and reframing the problems (Dorst, 2015), accelerates idea generation, and acts as material for designers to communicate the rationale of their decision. Earlier in this section, I mentioned that design thinking is an approach to creative problem solving. In the following section, I'd like to bring your attention to the fundementals of creativity and how it unfolds in practice.

3.2.3 Creativity- theory and practice

Creativity, in essence, is the process of producing novel, original, and valuable ideas for an open-ended task (Boden, 2007). It is powered by two distinct modes of thinking- namely, divergent and convergent thinking. The use of divergent and convergent thought processes is fundamental to creative thinking. (Goldschmidt 2014, 2016; Guilford, 1967; Osborn, 1953). While these concepts encompass the overall strategy to ensure creative output on a macro-level, in practice, these are often operationalised in the form of creative sessions containing several divergent and convergent activities. These are collaborative sessions often hosted by a person who is familiar with the creative techniques, known as the 'facilitator', guides a group of people (designers, users, or other subject experts), commonly known as resource groups, contributing towards an open-ended task.

Going back to the different thought processes, diverging, as proposed by Osborn (1953), is characterised by 'postponing judgement' and 'quality breeds quantity. This process is generative in nature, meaning it result in the development of new thoughts and ideas. While diverging helps produce many ideas, it also means that selecting the best of this lot becomes vital. Therefore, a diverging process is always followed by a converging process, which corresponds to reflecting and evaluating these ideas. This sequence of divergence and convergence led to what is commonly known as the 'creative diamond'. Tassoul and Buijs (2007) argue for an extra stage between divergence and convergence, where you neither add new ideas nor discard any ideas but organise them in understandable and recognisable categories. Heijne and van der Meer (2019) named this

> "Effective reasoning in a creative endeavour must perforce aim at first mining and then relating to one another the many items of data that are relevant to the task" (Goldschmidt and Tatsa 2005, p.595).

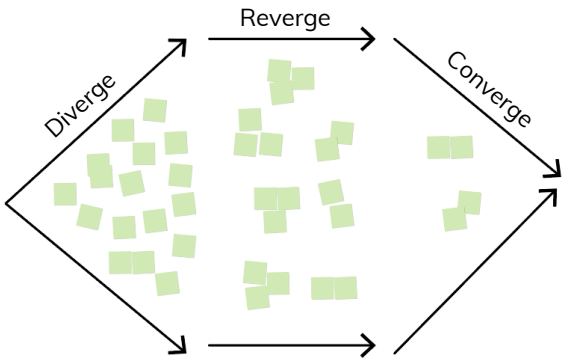


Figure 14: Creative diamond 2.0
(Heijne and van der Meer, 2019)

stage reverging- where the prefix ‘re’ stands for the four goals of this stage, namely “revisiting and rearrange options; to reveal and refine problem and solution space, reset and resource group dynamics”. They argue that looking back at the options generated, connecting ideas and identifying relationships will expand the knowledge and enrich the generated options. This sequential diverging, reverging, and converging model is termed the ‘creative diamond 2.0’.

3.2.4 Synthesis

Data in its raw form has the potential to inform designers about the happenings in the real world; however, it needs to be assimilated and transformed into information, knowledge, and wisdom (Ackoff, 1989). During the design process, designers attempt to draw connections between seemingly unrelated pieces of information obtained from contextual, competitive, or consumer research while trying to make sense of the situation (Kolko, 2010). This motivated continuous effort in connecting pieces to form a comprehensive understanding is called synthesis (also known as sensemaking). It plays a vital role in identifying opportunities in the scope of the design assignment.

While making these connections between data from several sources and about various events and interactions, designers add their prior knowledge, work, and life experience to the mix (Marsh et al., 1999; Ward, 1994). This enables them to make logical leaps even when the available data is often inconclusive and incomplete to paint the picture of the context. However, the ill-defined nature of the design also obliges designers to make many assumptions. Design insight is a combination of the subjective judgement of the designer and the objective data collected from the environment (Kolko, 2010). The leap discussed earlier is referred to as the ‘designerly’ way of working (Nelson & Stolterman, 2012; Cross, 2001; Moggridge, 2007) and is explained by ‘abductive reasoning. Abductive reasoning is “the argument to the best explanation” (Kolko, 2010, p. 7). It could be understood as the hypothesis that makes the most sense given observed phenomena based on available data and prior personal experience of the designer. Two striking differences between this mode of reasoning and more traditional reasoning (deductive and inductive) are that abduction leads to

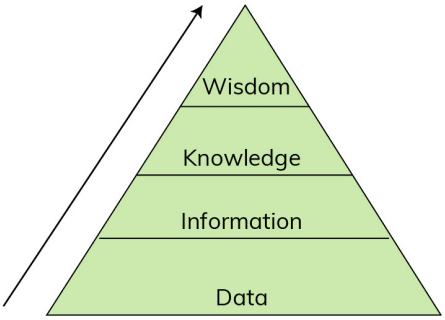


Figure 15: Data Pyramid (Ackoff, 1989)
Moving up the data pyramid is made possible by the process of Synthesis.

more questions than concrete answers and thus allows for new knowledge creation (Kolko, 2010).

Similar to what we saw earlier in the data visualisation literature, the element of externalisation also holds great significance in sensemaking in the design process. Especially when working in groups, which is more often than not in design projects, externalising becomes even more important as it helps transforms tacit (implicit) knowledge into explicit knowledge (Nonaka & Takeuchi, 1995). The act of getting it (individual's tacit knowledge) out allows for the idea to become a subject that can be shared with the rest of the members, that can be discussed, debated, and negotiated, contributing to the creation of shared mental model (Hey et al., 2007).

Concerning this project, I learn three essential components from this part of the literature: Firstly, exploratory inquiry on data visualisation will be one of the techniques that the designers deploy alongside several other research methods in their arsenal. Secondly, knowledge is born by finding connections between the available pieces of information. Externalising ideas and thoughts support this process and is crucial, especially when working in groups. Lastly, this part helps me justify the relevance and need for operationalising exploratory inquiring to enable the use of thin data early in the design phase.

How might we centrally store and manage insights from several studies conducted in a project? !?

Information obtained from several research methods and perhaps multiple iterations need to be compared, contrasted, and made sense of together. This would allow the designer to gain a better understanding of the context, draw a better picture of the situation, and enable easy navigation in the problem space. Therefore, how might we centrally store and manage insights originating from several studies?

Takeaways

Information plays an important role in the design process. It helps

- Manage uncertainty in the design process,
- Informs the framing and reframing of the problem to solve
- Accelerates idea generation, and
- Acts as material for designers to communicate the rationale of their decision

In design, sensemaking is made possible by adbuctive reasoning, which unlike other reasoning (inductive, deductive) results in more questions than answers.

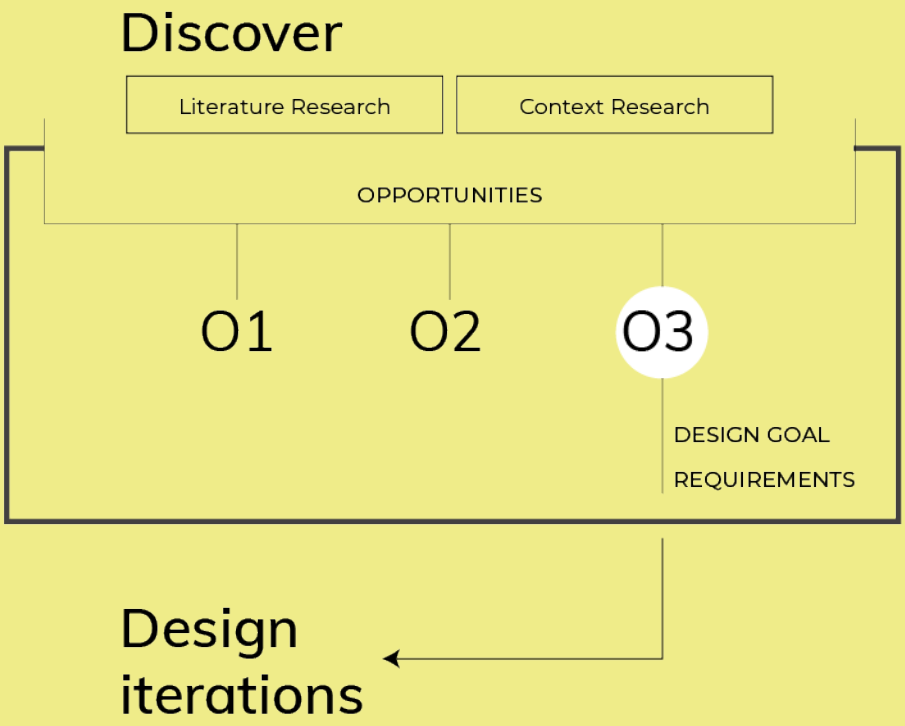
Exploratory inquiring on data visualisation is going to be one of the techniques that the designers would use in the extended process of user research, alongside several other research methods to understand their users.

Another important aspect of the sensemaking process is finding relationships and patterns between different observations and informations. This also applies for exploratory inquiring where finding connections between the questions would lead to a deeper understanding of the visualised data.

Externalising insights helps find these connections and also helps to build a shared mental model when working in groups.

4 Define

In this chapter, I discuss the three different opportunities identified based on the learnings from the Discover phase, out of which one is selected to progress with. The rest of the project will focus on designing and developing a solution pertaining to this opportunity. To support the process, I formulate design statement and requirements to inspire and guide the subsequent phase of the project.



4.1 Opportunities

Based on the insights from the Discover phase, I identify three opportunities that have sound potential in operationalising exploratory inquiring on data visualisation at the Ford SVC team. In this section, I outline the three opportunities, provide reasoning as to how they originated, and justify my choice of going forward with the third one in the project's next phase.

Opportunity 1: Trigger/foster designers to ask specific type of questions based on the purpose of exploration.

In Section 3.14, we saw that specific types of questions correlate to high design performance depending on the phase in the design process. For example, generative Design Questions are more favourable for diverging phases, and Deep Reasoning Questions are favourable for converging phases in the design process (Eris, 2004). It would be interesting to explore *How to implicitly trigger asking these specific questions to be encouraged when analysing a data visualisation based on the purpose of exploration.*

We saw in Section 3.11 that for exploratory data analysis, it is essential to be opportunistic, meaning the actions are driven by knowledge generated from the data in a bottom-up fashion. Therefore, deliberately making the designer ask a certain type of question may hinder with opportunistic exploration. Focusing on the type of questions to ask every time there is an interesting observation from the data visualisation will affect fluency of the exploration. Fluency refers to the number of ideas (or, in this case, questions) generated in a given time (Torrance, 1974).

Opportunity 2: Develop a digital tool that support exploratory inquiring by recommending relevant information from other studies

Information obtained from several studies must be compared and contrasted, and finding connections between them is important for the sensemaking process. This process allows the designer to understand the context better, draw a better picture of the situation, and enable navigation in the problem space. A digital tool that can retrive and recommend information from other studies of the project (or outside) in real time that are relevant to assist designers is an exciting opportunity to dwell into. This tool is envisoned to augment and possibly enhance the designers cognitive process in making these connections while exploring the data visualisation, supports their analogical-reasoning and hence improving the quality of questions/insights generated.

In my brief exploration of this direction, I learnt that this direction involves research and development of a system that can centrally store and manage insights across studies and projects. An key challenge would be devicing an algorithm to fetch relevant information based on keywords in the formulated questions from the insight corpus efficiently. Unfortunately, these are beyond my expertise and this project's scope, and I decided not to progress in this direction.

Opportunity 3: Conceptualise exploratory inquiring as a collaborative design method

Inspiration plays a crucial role in the design process. Inspiration can be described as mental stimulation to do or feel something, especially something creative (Gonçalves, 2016). Sarkar and Chakrabarti (2008) define stimulus as: 'An agent that activates exploration and search in design'. In this early stage of the design process, designers commonly seek external stimuli to frame and solve the problems of interest (Goldschmidt, 1997; Dorst & Cross, 2001; Gonçalves et al., 2013). We saw previously that interactive visualisations are more suitable for data exploration. Therefore, a promising area to explore is how interactive visualisations can be used as an external stimulus in a collaborative setting.

A vital factor to consider is that the structure of the SVC team allows for multidisciplinary collaboration. The team members are from different domains, so they bring different perspectives when collaborating in creative sessions towards a specific design task. This collaborative work allows one to share domain and data expertise through interpersonal and social interaction, leading to a better creative output. In simpler words, "the whole is greater than the sum of the parts"; working as a group will lead to better creativity than the individuals working separately. Therefore, developing a design method to transfer and circulate the procedural knowledge to conduct exploratory inquiring in groups is an exciting opportunity to consider.

Why this opportunity was chosen?

All three opportunity areas were intellectually intriguing for me to dive into. However, keeping in mind this project's scope in terms of time, resources, and my expertise, this opportunity was identified to be most feasible. In addition, the SVC team wants a solution that can be implementable in the near future with their current structure and resources. A solution that is actionable that can be put into use shortly after this graduation project. And for those reasons, I decided to pursue this option.

To gain theoretical knowledge of what constitutes a design method and to guide me to frame requirements for this design opportunity, I conducted a second literature review focused on design methods. The summary of my learnings relevant to this project are presented in the next page.

Methods in design

According to Simon (1996) (also a widely accepted view in the research community), designing is a human activity to change existing situations into preferred ones. Methods are a means to help designers achieve this desired change in a structured manner. Design methods come in many different forms. It could be as general as a set of heuristics or an algorithm-like template supporting a whole range of design processes (Daalhuizen & Cash, 2021). Altogether, methods have certain key benefits:

- Methods help externalise the thought process, making it possible for designers to critically reflect on their innovation process (Schön, 1983)
- Methods enable collaboration between professionals from various disciplines who may not be familiar with design. It provides a common vocabulary supporting the social interactions during the design process. (Jensen & Andreasen, 2010; Stappers & Sanders, 2013)
- In design education, aiding teaching and training students by making them aware of the design capabilities and how to hone them (van Boeijen et al., 2020, Andreasen, 2011, Cross, 2004).

Types of methods

In general, methods can be classified into two categories, based on their process of development, namely, descriptive or presctiptive methods. Descriptive methods correspond “How do people design”; they are developed by studying how expert designers typically carry out their design activity; codifying and standardising these practices for wider professional use (Jones, 1972). On the other hand, prescriptive methods correspond to suggesting - ‘How one should design’; that is, methods developed based on scientific knowledge of the design process, and how it could aid in rational and creative decision-making while designing (Bayazit, 2004). In this project we are focused on presctiptive methods, that is the theorotical knowledge from the areas of data visualisation, creativity, and design theory are used to conceptualise a design method prescribed for the use in the SVC team.

Method development

We saw previously that design methods capture the key procedural knowledge, supporting the design process, practice and education. In relation to this project, I explored the literature about different components of a design methods and how they affect the performance to aid me in conceptualising exploratory inquiring on data visualisation as a design method. To my best effort, I was not able to identify much literature from the past that provides a clear and complete description of the different componenets of a design method. Recent studies from Daalhuizen & Cash (2021), provide a robust explanation of the method use and a comprehensive understanding of how design methods work. Method Content theory (Daalhuizen & Cash, 2021) helped me get a good grasp of design methods and directed me to think the about certain requirements that I need to attend to, in the path of conceptualising exploratory inquiring as a design method.

Method Content Theory

Method content refers to comprehensive description that enables the execution or practice of a design method. According to Daalhuizen & Cash (2021), the elements that make up a method content are the Method Goal, Procedure, Framing, Rationale, and Mindset.

- **Method Goal:** What design goals will the method help to achieve?
- **Method Procedure:** Information about a specific way of working.
- **Method Rationale:** Relevance and justification of method goal in context.
- **Method Framing:** When and where the method can be used in the design process.
- **Method Mindset:** The required mindset that the user needs to adopt

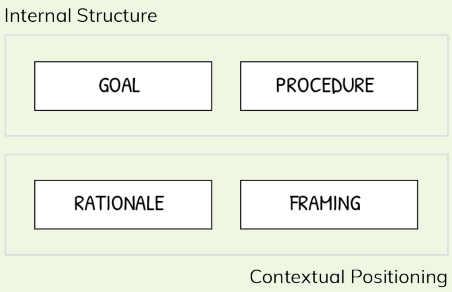


Figure 16: Different elements of the method content (Daalhuizen, 2021)

The goal and procedure correspond to the internal structure of a method content that is, providing prescriptive information about the intended purpose the method helps to achieve and the associated steps that needs to be followed to reach the goal. The Framing and Rationale deal with the contextual positioning of the method in the broader design process and the organisational context. This can be understood by the questions when, where, and how the designer should use the method and why this method should be used in the given situation. The method mindset is tightly linked with the designer's perception of internal logic and contextual positioning; that is, to what extent does the designer have the situational awareness and belief that the method will help to achieve the goal. Developing a mindset involves extensive and prolonged study into the context and use of the method, and hence considered out of scope for this project. In this project, I will focus on developing content for the method to practice exploratory inquiring for the four elements- Method goal, procedure, framing and rationale, along with the associated information artefact. Information artefact refers to the embodiment of the method content, that is, tools used to store, manipulate, and display information during the method use (Green & Blackwell, 1998).

4.2 Design goal

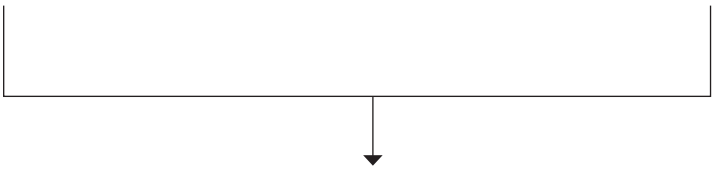
Based on the research from the Discover phase, I first describe the current and desired situation of the SVC team and the change that this project is trying to achieve. Following that, I formulate a design statement, highlighting the different levels of benefits that the solution must fulfil.

Current situation

The SVC team primarily relies on thick data from qualitative research methods to get to know about the needs of their users and the context early in a design project. They have access to aggregated thin data (for example, collected from one of the sensors in the car), which are not being used for creative purpose. While thick data provides insights into users' context, emotions and needs in an in-depth manner, big data can offer a broader perspective that represents a large population with great granularity.

Desired situation

The SVC team incorporates thin data into their design process, whenever they find it relevant. The project owner is empowered with the design method and is able to host creative sessions, where the members of the SVC team collaboratively explore and derive insights from the available dataset. By following a certain procedure, set-up and rules of engagement, they can systematically discover new insights that inspires and informs the creative design process.



Design Statement

Design a method and a toolkit for the Smart Concept Vehicle team that support them in systematically exploring thin data to generate insights that inform and inspire early in their design process.

4.3 Requirements

In this section, I will first outline the final solution's requirements, followed by a brief explanation describing their relevance in this project. I formulate these statements (design requirements) to qualitatively express the traits and characteristics of the to-be-designed product (Hekkert & van Dijk, 2016). The requirements originated as a result of the collective learnings from the Discover phase relevant to the chosen opportunity. They inspire me to navigate the solution space and specify boundary conditions to stay pertinent to the scope of the project..

R1 Encourage externalisation

The solution should encourage extenalisation of insights in the form of questions.

We saw in section 3.2, that externalising insights plays an important role in generating knowledge, even more so when working in groups. It makes the idea 'real' that can be discussed and reflected on, contributing to building a shared mental model. We saw earlier that questions are potent carriers of insights and is a powerful tool to organize information about things we do not know (Berger, 2016). Its is useful to keep track if newly found information and also to capture lack of information, indicating the need for exploration. Therefore, the solution should allow for and encourages noting down the question that arise during analysing the visualisation

R2 Foster interaction

The solution should create an environment that fosters interaction.

Two types of interactions are essential when devising a set-up for collaboratively exploring data visualisation. The first is the social interaction between the group members, which allows for interpersonal communication that harnesses the power of transdisciplinary collaboration. It should provide an environment where each of the members can freely express their ideas and contribute to the collective knowledge emanating from their field of expertise and experience. The second is the interaction between the human and the visualisation tool that allows for direct manipulation, which changes the state of visualisation in real time, leading to efficient analysis. Therefore, the solution should create an environment conducive to these two types of interactions.

R3 Embody EDA principles

The solution should embody the principles of exploratory data analysis.

We saw in Section 3.1 that EDA could be best described as an opportunistic attitude, and no one set a procedure for carrying out the analysis. The actions are often driven by what is learnt from the data. However, we identified certain heuristics that can assist in developing such an attitude. Therefore, it is essential to embody these principles when conceiving the design method.

R4 Convivial Intervention

The solution needs to integerate with the available technological resources of the SVC team.

The SVC team is looking for a solution that they can readily implement in the near future. So, the solution needs to take into consideration the feasibility in terms of technological resources (both hardware and software) available with the target group. Several technologies for example. interactive table top displays, allows for shared focus or shared attention when working in groups, enhancing collaboratively analysing a data visualisation. However, the SVC team only have access to single-user display devices like laptops and monitors, and larger displays like a projector screen or television in conference halls. In terms of visualisation tool (software), they are familiar with novice tools like Excel and Qlikview, that enable visualising data sheets without much of programming expertise. The solution needs to stay within the bounds of available technology.

R5 Embrace Approach

The to-be-designed solution should fit into the existing design thinking framework (Section 2.3).

The SVC team employs the Ford x IDEO design thinking to give an overall structure to their projects, to communicate the progress with their peers and managers. Despite the fact that the framework is not actively referred in their day-to-day operations, it plays an important role establishing a mutually agreed language and an overarching mindset among the members of the team. Therefore, it is necessary that the solution fit into their current design thinking framework.

R6 Mindful of Expertise

The solution should be suitable for designers who are non-data experts.

The SVC team comprises people from multiple engineering backgrounds, who are experienced design thinkers, but not all of them are experts in data practices and data analysis literature. Although they can handle data and data processes that do not involve extensive programming, it is important to be mindful of their strengths, which are critical and creative thinking in their domain of expertise. The solution must factor in this crucial criterion; the method should be accessible to designers who are not data experts, and should consist a linear guideline to carry out analysis with concrete examples of associated steps.

R7 Cohesive method elements

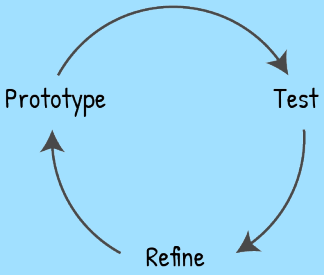
The solution should clearly communicate the different elements of method content.

We saw previously that a good design method must provide content for both internal logic and contextual positioning. Furthermore, the elements of a method content (The goal, procedure, rationale and framing) must provide sufficient clarity to the user of the method to logically asses the suitability of the method in the situation and its effective application for a design task. Therefore, the final deliverable should effectively communicate the method elements, enabling the SVC team members to carry out the method without any external assistance that is self-explanatory and provide all the necessary tools needed to execute the method.

These seven requirements form the building blocks in formulating the method for exploratory inquiring on data visualisation. They are the starting point for the next phase of the project, where the solution will be prototyped, tested and refined iteratively.

5

Design Iterations



This chapter entails the iterative development of the solution, the design method to practise exploratory inquiring on data visualisation. Based on the design goal and requirements formulated in the previous chapter, a preliminary concept was conceived, which was then prototyped, tested, and refined iteratively for three cycles. The details of these iterations and the results of the studies are discussed further in this chapter.

5.1 Introduction

Based on the insights gathered from context and literature resarch, a preliminary concept was develped in the form of a design method (Section 5.1). This chapter describes the three studies that were carried out to test and refine the procedure of this preliminary concept. These studies were formative in nature, meaning the goal of each study was to understand designers behaviour to the set-up and procedure of the method, reflect the challenges and improve on them iteratively in the subsequent versions. The first two studies were conducted with student designers and researchers, while the third study was conducted with the members of the Ford SVC team. The activities carried out and the breakdown of the sections in the chapters are discussed below:

5.2 Overview

As duscussed previously, the design iterations followed an prototype-test-refine approach.

Prototype

The prototype concept method was conceived based in the requirements and learnings from the literature for the first iteration. For the next two iterations,

Test and execute

The prototype method procedure was executed for a hypothetical project with a central question "*How can the charging experience for Electrical Vehicles be improved?*", a topic similar to current projects at the SVC team. I took the role of project owner, meaning I selected a dataset, prepared the visualisation, hosted and

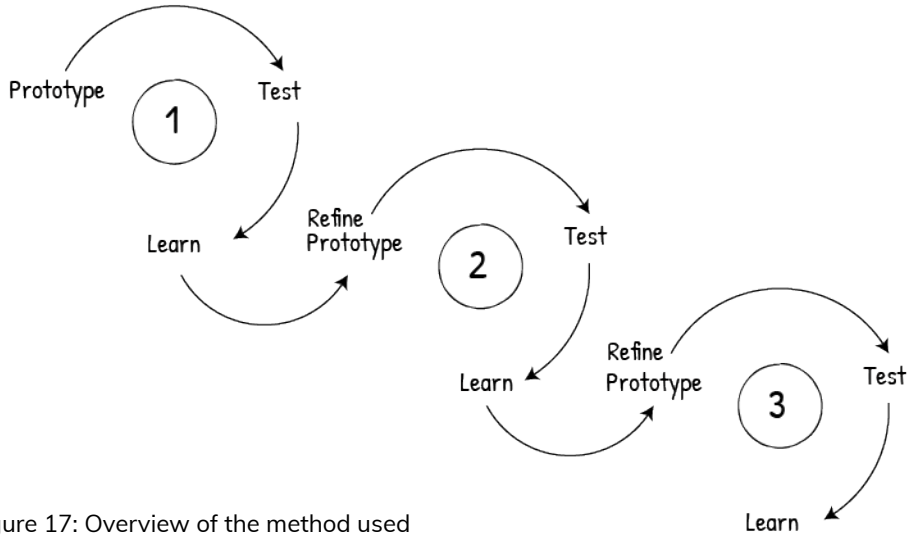


Figure 17: Overview of the method used for the design iterations.

Iteration #	Resource group		Set-up
1	Nº6	Students, Researchers, TUD	Online
2	Nº3	Students, TUD	In-person
3	Nº4/3*	Designers, SVC team	In-person

Table 1: Overview of the formative studies conducted.
* One of the participant from the first session was not able to participate in the next one.

facilitated the creative sessions. In the third cycle, as we wanted to test the method with an internal dataset, I was accompanied by the company mentor to act as a co-project owner to maintain data privacy.

Reflect and Learn

The creative session proceedings were documented using field notes and audio recordings. These were analysed using the reflection framework- 'what, so what, and now what', and the most promising insights are presented as learnings.

For the third iteration, two additional steps were carried out. First, the questions noted down were coded based on the taxonomy of questions proposed by Eris (2004) to understand the type of questions that were prominent during each activity and implications of the question to the next possible step in the design process. (see next page). Second, individual reflection interviews (every 30 mins) were conducted with the participants to understand their experience with the creative sessions better.

Refine

Based on the learnings from each iteration, the method procedure was refined and improved, addressing the challenges observed during the period.

The details of each iteration are discussed in the following sections.

A

Deep Reasoning Questions
Interpretation
Procedural
Causal Antecedent
Causal Consequence
Rationale/function
Expectational
Enablement

Generative Design Questions
Enablement
Method Generation
Proposal/Negotiation
Scenario Creation
Ideation

Low-level Questions
Verification
Disjunctive
Concept completion
Feature specification
Quantification
Definition
Example
Comparison
Judgemental

B

Clarification regarding dataset
Clarification regarding domain
Could be answered by new visualisation
Need for further qualitative research
Directing to exploration into ‘solution space’

Figure 18: Coding Schema
A Based on Eris’s question taxonomy (left), and
B Implications to the design process (right)

5.3 Iteration 1

5.3.1 Prototype

I use method content theory as a scaffolding structure to communicate the different elements of the concept. In this section, first, I present the goal, rationale, framing and reasoning behind the conceived procedure, followed by the procedure itself (on the next page).

Goal:
To generate insights from big-thin data, to inform and inspire the design process by systematically asking and reflecting on questions when exploring interactive data visualisations.

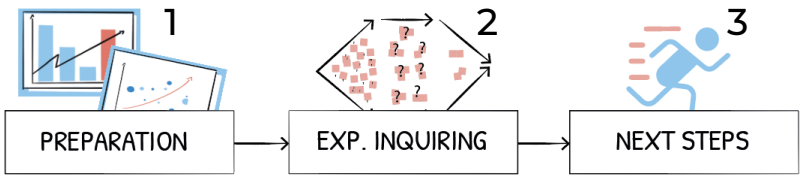
Rationale:
While thick data provides insights into users' context, emotions and needs in an in-depth manner, big data can offer a broader perspective that represents a large population (Pavliscak, 2015) and a granular lens on their behaviour over a large period. In Section 2.2, we saw that the SVC team has access to big data, which is not used to its full potential for creative purposes. Therefore, introducing this emerging source of information into the early stage of design in addition to the already used thick data to better understand the users will positively impact exploring and navigating the problem space.

Framing:
We saw previously (Section 3.1) that information is important throughout the design process. The method of Data Interrogation provides a systematic way of generating information from big data to support the creative purpose. Ideally, it can be used at any phase of the design project. However, keeping in mind this project's scope, I intend to test and develop the method for the first phase of the Ford Design thinking cycle- the Gather Research and Inspiration phase of the Ford x IDEO design thinking framework.

Reasoning for the procedure:
The foundation of this concept lies with questions, as questions are powerful tools to carry insights; By systematically asking and reflecting on questions when exploring interactive data visualisations, we make the insight generation process efficient. To structure the inquiring process, I adopt the different stages of the creative diamond 2.0 model to structure the inquiring process. Firstly, to explore the interactive visualisation and externalise the questions as a diverging activity, then revisiting and refining the questions as a reverging activity, and finally, choosing the most interesting questions to move forward in the design process in the convergent activity. This choice was made because the divergent thinking from the creative diamond 2.0 closely resembles the opportunistic exploration required for exploratory analysis and helps in the easy transfer of skills and mindset. We saw earlier that finding connections between the insights lead to newer and presumably better insights. Therefore, I propose to deliberately reflect on these questions in search of a pattern in the reverge activity. Lastly, the converge activity will help to obtain a tangible set of insights to inspire the next steps that the project owner can act upon.

This concept was tested using a formative study, whose details are explained in the next section.

Preliminary concept



Project Owner **Resource group (Ideally, 5-8)**

1

Preparation of interactive visualisation

- Gather pre-processed data in the form of data sheets either from GDIA or external source relevant to the central question.
- After initial exploration, create an interactive visualisation
- Invite suitable members to participate in the creative session, exploratory inquiring.

2

Creative session, Exploratory Inquiring

- **Introduction** Introduce the participants to the central question, goal of the session, the dataset, and the visualisation.
- **Warm-up** Discuss and list the possible stakeholders in the scenario corresponding to the dataset and think from the stakeholder's perspective about what they would like to know from this dataset.
- **Diverge** Read, discuss, and analyse the visualisation. Note down insights in the form of questions that emerge from the activity.
- **Reverge** Reflect on the questions posed in the previous activity, rearrange, and cluster them based on their conceptual meaning.
- **Converge** Select the most interesting clusters/ questions and discuss the next steps that could be taken to address them.
- **Reflect** Discuss on the activities carried out during the session, what worked and what could be improved.

3

Next steps

- Based on the outcome of the session, prepare for the next steps in the design process, like exploration, ideation, or prototyping.

5.3.2 Execute

Project Owner **Resource Group**

Project Owner	Resource Group
Vignesh Balakrishnan	A total of six people with a design background participated in the creative session. These include one student and three researchers involved in the URP from TUD, and two members of the SVC team.

1 **Dataset Exploration**

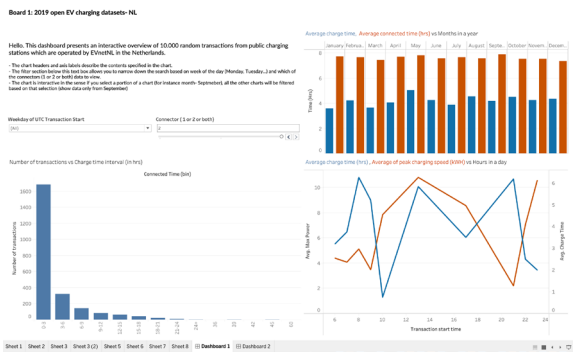


Figure 19: Interactive visualisation used for the session.

Dataset used

ElaadNL is a knowledge and innovation centre in the field of smart electric vehicle charging in the Netherlands. They published an open data set of 10,000 random public charging transactions in the Netherlands (Elaad, 2021). This corresponds to aggregated data (Section 2.3), containing details about public electric car charging over a period of 1 year.

Visualisation tool

The software 'Tableau' was used to create an visualisation dashboard, containing 3 graphs- 1 scatterplot and 2 bar graphs with interactive filters.

2 Preparing the data visualisation

Session set-up
Online

Visualisation
via Screen share

Workspace
Digital- Miro

Figure 20: Visual Representation of the set-up of creative session.

Transaction ID	The unique transaction code.
ChargePoint ID	The unique code of a charging station.
Connector ID	Many charging stations have two connections (two sockets for charge plugs) and this indicates what connector was used for the transactions.
UTCTransactionStart	The moment the transaction was started (logged in locale time zone).
UTCTransactionStop	The moment the plug was disconnected and the transaction was stopped.
StartCard	The RFID card (hashed) which has been used to start a transaction.
Connection Time	Time difference between the start and end of a transaction.
Charge Time	Total time wherein energy transfer took place.
TotalEnergy	The total energy demand (kWh) per session.
MaxPower	The maximum charging rate (kW) during a session.

Figure 21: Datafields and description as shown to the participants

Introduction: 30 mins

The participants were introduced to the goal of the session- to generate insights on user behaviour and needs relating to the central question How can charging experience for electric vehicles be improved? Following that, the dataset and the data fields were introduced along with a brief description of what each data field entailed.

Warm-up: 5 mins

As a warm-up activity, the participants were asked to list the possible stakeholders in the scenario corresponding to the dataset and think from the perspective of the stakeholder what they would like to know from this dataset.

Inquiring: 25 mins

Participants were asked to analyse the data visualisation and note down insights in the form of questions on (digital) sticky notes. The following tips were given to induce the diverging mindset required for this activity. *Be openly curious, postpone judgement, Quantity breeds quality, what would your stakeholder like to know?*

The rest of the planned activities in the creative session were not executed due to the reasons discussed in Section 5.1.2.

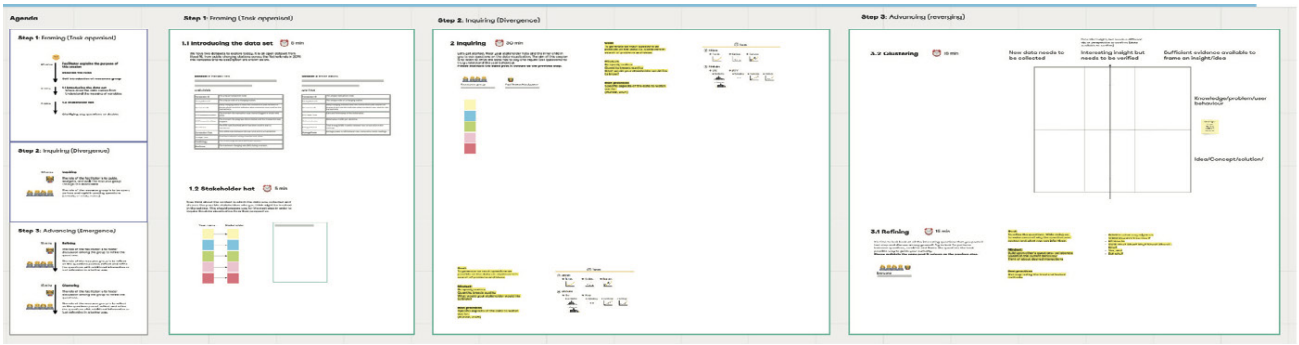


Figure 22: Online worksheets provided during the session.

5.3.3 Learn

L1.1 Trouble inquiring without a richer understanding of the dataset.

Participants struggled to read and understand the interactive data visualisation in a short amount of time. They were not able to analyse and derive insights as there was confusion as to what each of the data fields (measurements) meant and the what real life events that these represents. A significant amount of time (around 30 minutes) was spent in clarifiying the information and answering questions, which left no room to continue the other planned activities of the session. These questions were pertaining to the context of data collection, the variables, and the rationale behind the choices of visualisation made from the dataset. Although they understood the meaning of each of the datafields individually, a deeper understanding and immersion into the context where the data was collected is required to empathise and be able to extract insights from the visualisation.

> *"We are now completely lost. You know the data set because you prepared it. (The dashboard)". P2*

L1.2: Lack of focus

Although early in the design process, and it is favourable to have access to as much information as possible available for exploration, there was a lack of focus when trying to analyse the visualisation. Participants indicated that they prefer to have a funnel down (choose a subset) the available data relevant to their topic of interest and visualise the selected measures.

> *"If I know what we have to find out, I can look at the data and make sense of it, construct a story in my head. If I don't know don't really know what I'm supposed to do with data, it's hard for me to be motivated to jump into the point of data." P1*

L1.3 Need to be involved in the process of selecting what visualization need to be made

It was observed that the participants were overwhelmed by the amount of information presented in the interactive visualisation. One reason for this could be that all these graphs were introcued all at once and that only a brief description of the graphs (This is the graph- these are the axes- these are the filters and interactive features) were given at the time of introduction.

> *"When you were talking about this graph, I was actually trying to understand the other graph" P2*

The visualisations created were based on the knowledge that I had about the topic and what I found to be interesting to visualise with the available dataset. This involved making multiple decisions on the visual structure (Section 3.2) and the choice of data fields to visualise. It is important to take into consideration that the decisions were subjective based on my level of expertise with the topic, data visualisation, and also the software tool. It was observed that participants would like to be involved in the process of creating the visuals that they would like to analyse. They expressed interest in getting involved in the process of creating the

visuals or at least the decision making that is involved in creating the visuals.

> *"Why did you choose (to show) these graphs and not others?" P1*

> *"In the filter, you actually disable to show what's difference (in number of transactions) between weekdays and weekend days" -P4*

The GSP (Generate-Stimulate-Produce) model of creativity in conceptual design (Jin & Benami, 2010), talks about how a design entities created by designers themselves (infomration, sketches, artefacts) are found to be the most important source of stimuli driving a designer's creative thinking process. In case of the method- 'Data Interrogation', the design entities correspond to the interactive data visualisation used as an external stimulus that is used to inspire designers to ask questions. In other perspective, I speculate that the perceived effect of the inspiration goes up due to what is commonly known as the 'Ikea effect', which brings in a sense of ownership and trust on the inspiration material. Therefore, it seems logical that the participants of the creative session (designers) expressed interest in being part of creating the inspiration material.

L1.4: Set-up shortcomings

As mentioned before, the session was conducted in an online setting. Participants had trouble viewing and working in multiple windows (Video call- Zoom, Visualisation dashboard- Tableau, and Online whiteboard- Miro) all at once. It was further challenging to carry out the activities when they had no access to an additional screen/monitor at their disposal.

> *"I cannot look at the data (visualisation) and post at the same time. Maybe organize the screens differently so that I can take a look at both at the same time." P1*

5.4 Iteration 2

5.4.1 Refine

The learnings from the first iteration highlight two major shortcomings with the previous prototype method procedure. These are formulated as design challenges as follows:

How to deliver richer background information while introducing the dataset?

How to involve the resource group of the creative session in deciding what visualisations need to be created?

As the project owner is usually not an expert in data visualisation, it would take considerable time and effort to understand the visualisation request, prepare the datasheets, and create the visualisation. Therefore making visualisations on the spot during the session is ruled out, keeping in mind the time cost of the resource group. Therefore, hosting a creative session prior to the session- 'Exploratory Inquiring', with the same resource group to take in suggestions of what visualisation needs to be made, is considered more logical. In addition to giving sufficient time for the project owner to reflect on the suggestions and prepare the visualisation, it also allows the resource group to explore the dataset in detail and reflect on where they expect to find insights.

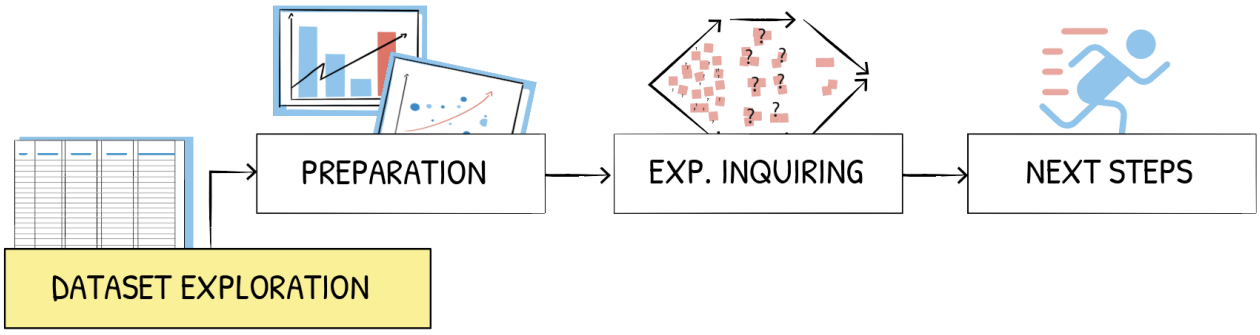


Figure 23: Refined procedure. Modified element highlighted in yellow.

Rationale- Dataset Exploration

1. Storytelling

As observed in the first iteration, introducing the dataset with a verbal description of the data fields was insufficient to grasp what the measures reflect about the users' actions. Storytelling is embedded in design practice in several forms and purposes (Beckman, 2009). A narrative in the form of a story can turn abstract concepts into a concrete and understandable form. This tool is also widely used in the data visualisation community to communicate the result of analyses. (Knaflic, 2015). By sharing the dataset bundled in a user scenario, the abstract nature of measured variables will be associated with the different elements in the narrative and provide a closer connection with the data points. Hence, I propose to use storytelling as a tool to introduce the dataset and the scenario in which the different values are measured to better understand the dataset and corresponding data fields.

Additionally, I propose using images to further strengthen their understanding. Several researchers have shown that visuals have a good influence on creativity. For example, Leclercq & Heylighen (2002) indicated that using visual stimuli led to designers creating more ideas, not just in quantity but also in quality (Goldschmidt & Smolkov, 2006). Spalburg (2021) also noted that the SVC team members perceived visual stimuli as more engaging in their typical creative sessions. Therefore, in the next iteration, I plan to execute this by using annotated pictures to support the narrative during storytelling.

2. Stakeholder Search

This is an activity that was part of the previous iteration that allowed the resource group to think about the different stakeholders involved in the context of data collection and their aspired insights. This activity is maintained without any change as it received a positive feedback from the participants of previous session. The rationale behind this activity is to step in top the shoes of the stakeholders (which also includes different type of users) and try to understand the situation from their perspective. In other words, an opportunity to empathise with the people involved in making the scenario of data collection. This helps to trigger curiosity questions from the perspective of different stakeholders, which would help in the next step of suggesting visualisations.

3. Visualisation Suggestions

While creating the visualisation, the creator makes certain assumptions about the choice of data fields and how to encode them based on their knowledge and beliefs (Munzner, 2014). As seen in Section 5.1.2, the need for the resource group to be involved in creation of visuals were evident. In order to assist the project owner and at the same time give the resource group an opportunity to take part in the decision-making process, this activity was introduced as part of 'Dataset Exploration'.

No changes were made to the remaining part of the procedure as no new insights were found regarding them in the first iteration.

Refined concept

 **Project Owner**

 **Resource group (Ideally, 5-8)**

1

Creative session, Dataset Exploration

» Introduce the central question of the project and the goal of the session- To identify and suggest data visualisations to be made from the available quantitative data.

» **Storytelling** Introduce the dataset and data fields narrated through a story describing a scenario in the context of data collection.

» **Stakeholder search** Discuss and list the possible stakeholders in the scenario corresponding to the dataset and think from the stakeholder's perspective about what they would like to know from this dataset.

» **Visualisation suggestions** Discuss and note down the combination of data fields that would inform and direct towards the aspired insights.

» **Reflect** Discuss on the activities carried out during the session, what worked and what could be improved.

2  **Preparation of interactive visualisation**

3  **Creative session, Exploratory Inquiring**

4  **Next steps**

Refinements

This corresponds to the improvements made to the procedure upon the learnings from the previous iteration.

5.4.2 Execute

Project Owner **Resource Group**

Project Owner	Resource Group
Vignesh Balakrishnan	Three students pursuing master's at TUD were recruited. Two of them had a background in design, while one was from a non-design background (Transport Infrastructure and Logistics). This sampling was done to emulate the composition of the SVC team.

1 **Dataset Exploration**

Dataset used

ElaadNL open data set of 10,000 random public charging transactions in the Netherlands (Elaad, 2021) containing details about public electric car charging over a period of 1 year.

Figure 24: Example of an annotated picture used for introducing the dataset.

Introduction: 10 mins

The participants were introduced to the goal of the session- to suggest visualisations to be made from the available dataset and to the central question How can charging experience for electric vehicles be improved?

Since the participants were not familiar with the context of this project, a brief introduction to the graduation project was also included as part of this activity.

Storytelling

The dataset was introduced using storytelling. It included a verbal narration describing a scenario of data collection. It was supported by few annotated pictures to provide a sense of where this data might have been collected. For more details, refer Appendix D.

Stakeholder search
As a warm-up activity, participants were asked to list the possible stakeholders in the scenario corresponding to the dataset and think from the perspective of the stakeholder what they would like to know from this dataset.

Visualisation suggestions
Participants were asked to discuss the combination of data fields that would inform and direct towards the aspired insights, and make suggestions for visualisations that they would like to be made for analysis.

2 Preparing the data visualisation

Due to practical constraints of the participants, both the sessions had to be conducted back-to-back with only 30 minutes of break in between. Therefore, it was not possible to make new visualisations and the ones made for the previous iteration were utilised.

3 Exploratory Inquiring

Session set-up
In-person

Visualisation
On big screen

Workspace
Digital- Miro

Figure 25: Visual Representation of the set-up of creative session.

Introduction: 20 mins

The participants were introduced to the goal of the session- to generate insights on user behaviour and needs relating to the central question How can charging experience for electric vehicles be improved? Following that, the data visualisation was introduced one by one.

Diverge: 15 mins

Participants were asked to analyse the data visualisation and note down insights in the form of questions on (digital) sticky notes. The following tips were given to induce the diverging mindset required for this activity. *Be openly curious, postpone judgement, Quantity breeds quality, what would your stakeholder like to know?*

Reverge: 15 mins

Participants were asked to look back at the questions posted in the previous activity, and were asked to cluster them. They were allowed to reformulate the questions and even go back to the visualisation for clarifications.

Converge: 10 mins

Participants were asked to select the cluster/questions that they would like to follow up or explore further, and discuss how they would go about it.

Reflection 10 mins

The participants and I collectively reflected on the activities from both the sessions, what went right and what could be improved.

5.4.3 Learn

L2.1 There was a better understanding of the dataset and data fields.

The dataset exploration session provided the resource group with a chance to familiarise themselves with the background information of the dataset and get immersed in the data collection scenario. Introducing the dataset as a story helped participants grasp the measured values represented in the data fields, clarified their doubts about the dataset, and fostered good discussion around the topic. In one such discussion, I observed the a participant showcased the use of analogies to explain an unkown/not fully known concept related to the dataset. Analogies are an important cognitive tool to transfer the knowledge about the source concept (here mobile charging) to understand the target (electric vehicle charging) to better understand the and draw inferences. Another observation is that not many questions about seeking clarity on the data field or data collection were posed in the exploratory inquiring session. There was a good flow in question-asking behaviour compared to the first iteration.

> *"So, it is like when you are charging the phone overnight. It is connected for 8 hours, but probably already fully charged in the first few hours". P1*

L2.2 Need to support communication of visualisation specifications

It was observed that in the dataset exploration session, every participant had their style of communicating the specifications of visualisation. For example, one participant made a visual representation while the other made a list of data field combinations. The diverse form of communication was a problem during the preparation of visualisation to compile the inputs from all the participants in a short time. Although this does not represent the actual use case where the project owner will have more time than 30 minutes to process the requests and create the visualisation, making the process more streamlined will make the activity more desirable and usable. Therefore, a standardised way of communicating what visualisation needs to be created, with details about visual structure and data fields, would make the process better for both the sender (resources group) and receiver (the project owner) of the information.

In addition to diverse styles in communicating the visualisation specification, it was observed that none of the suggestions specified interactive elements. One reason for this observation could be that the participants were unaware of the interactive features or needed to learn how to convey them effectively. Either way, supporting the designers with tools and information that help them make suggestions would be favourable.

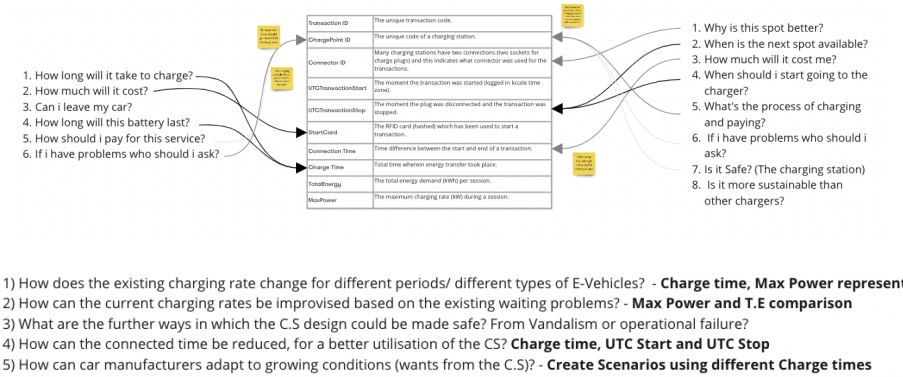


Figure 26: Participants different modes of communicating the suggestions for visualisations.

L2.3 Lower than expected engagement

Isenberg et al. (2011) defines three levels of engagement in collaborative visualisation: viewing, interacting, and creating. Viewing corresponds to passive consumption of pre-selected information and visualisations, interacting/exploring corresponds to actively taking initiatives in conversing with the visualisation system to play around and change the state of visualisation, and creating refers to making, uploading, and sharing new visualisations. For the creative session- Exploratory Inquiring- we were aiming for the second level when the collaborators actively exchange information with the visualisation system through interactive features.

However, in the current setup, the visualisation was projected on the big screen allowing all the participants to have a shared view. This was done to mimic how materials from qualitative studies are shared with the participants during the creative sessions of SVC (Section 2.1). This setup allowed participants to indirectly access the interactive features, that is, by communicating the action that needs to be performed to the facilitator. However, it was observed that the participants could not actively engage with the visualisation during the session and hesitated to give the facilitator instructions. One reason for this could be the social inhibition that the participants faced to express their requests, and another could be that the setup did not allow for easy interaction between the user and the system. Either way, this hindered active exploration, which needs to be addressed in the next iteration.

2.4 Way forward- contextualising insights

Contextualising is one of the blending strategies to combine the thick and thin data. Signs of going forward in the design process with this strategy were observed

in the creative session. For instance, the resource group generated an insight- that people prefer one type of public charger (of the available 2 types) throughout the year. However, although this inference provided information about a 'fact', they could not conclude without having more information about the context. There was a discussion on several other factors that could have influenced this phenomenon. But unfortunately, since not much more contextual information could be derived from the available dataset, it was not possible to conclude. This example demonstrates the need for qualitative follow-up studies to add the 'Why' or search for more contextual information to support the insights obtained from the quantitative data.

"I guess this (why users prefer one charger side over other?) could be because of geographical or geometric reasons or because charger 1 is more powerful than the other, but I cannot say anything for sure now (with the available data)" P2

L2.5 Questions inspire questions

A pattern of participants being inspired by the discussion and questions posted by other participants were observed and later confirmed at the time of reflection. It was also observed that even at the time of reverging activity, participants had inclination to reformulate some of the questions based on the new 'meta' information that they derived from the rearranging process. This also led them to go back to the visualisation and look for more information fostering exploration.

"(I) drew inspiration from others' question and asked better questions" P2

"We all see the same data right. But the way we are formulating and reformulating the questions allow us to see and interpret (the data) better " P1

L2.6 Personal reflection: Building a story triggered recall of past experience with conext.

While preparing materials for this study, one of the tasks that I had to execute was to construct a narrative to help me with the activity of storytelling to introduce the dataset. This made me think about the past experiences that I've had with electric charging spots and recollect the associations that I had with such experiences. Also while collecting pictures to support the story, I had to quickly browse in search of images from the internet. Although not the most accurate representation of the particular charging station from which the data was collected, looking up for images of various electrical charging stations helped improve my contextual understanding and various factors that are responsible for providing a better charging experience. Therefore, for the next iteraion, I wish to experiment with shifting the storytelling activity to the resource group side. In addition to stimulating them to think about their personal experiences, I also expect the insights from some of their previous studies in this topic to surface and help the collaboration.

5.3 Iteration 3

5.5.1 Refine

Visualisation canvas

One of the primary goals of the session- 'Dataset Exploration' was for the participants to provide suggestions for visualisations that could be made from the available dataset. This could be a direct combination of data fields where they'd like to see how one measure changes with respect to the other; for example, 'I'd like to see how charge duration is varying over the time of day" or one with an interactive component, 'how does charging duration change over time of day filtered across different months". Per the learning from the previous iteration L2.2, the following design challenge was formulated:

> *How to support the resource group communicate their suggestions for interactive visualisations?*

After several quick iterations, a canvas- a shared space where the resource group can fill out to mark their suggestions were created. Tokens were made to make the participants aware of the interactive components and allow them to use them specify while suggesting visualisations. They were based on the common interactive elements of data visualisation (Heer and Schneiderman, 2012) such as:

- **Sort: To suggest a sorting order.**
- **Filter: To create sub groups or subsets within the data field.**
- **Create: To combine data fields to create a new data field. (Binning)**

Storytelling

In response to L2.6 from Section 5.2.3, I decided to shift the activity of storytelling to the resource group. This acts as an opportunity to share insights from past experience and other qualitative studies (Section 3.2) with the rest of the resource group (if any). As the members of the SVC are multi-disciplinary and not necessarily everyone is from a background in design, I propose to provide tips to construct a story. In this iteration, Replacing the role of annotated images, I propose to introduce the dataset using a collage of images representing the context of the dataset (to be prepared by the project owner) as a visual stimulus source.

Change in set-up

We know that working in groups enhances creative thinking process (Paulus & Nijstad, 2003); however, in exploration in data visualisation is often carried out individually. The set-up used for the previous iteration did not allow for active engagement and interaction with the visualisation system. Therefore, in response to L2.3, I propose to split the group into smaller teams of two when carrying out the inquiring activity where each pair have access to the visualisation on their personal computer. This way, there is a social element during the analysis where discussions positively affect exploration, and at the same time, there is a closer contact and less inhibition to interact with the visualisation system fostering exploration.

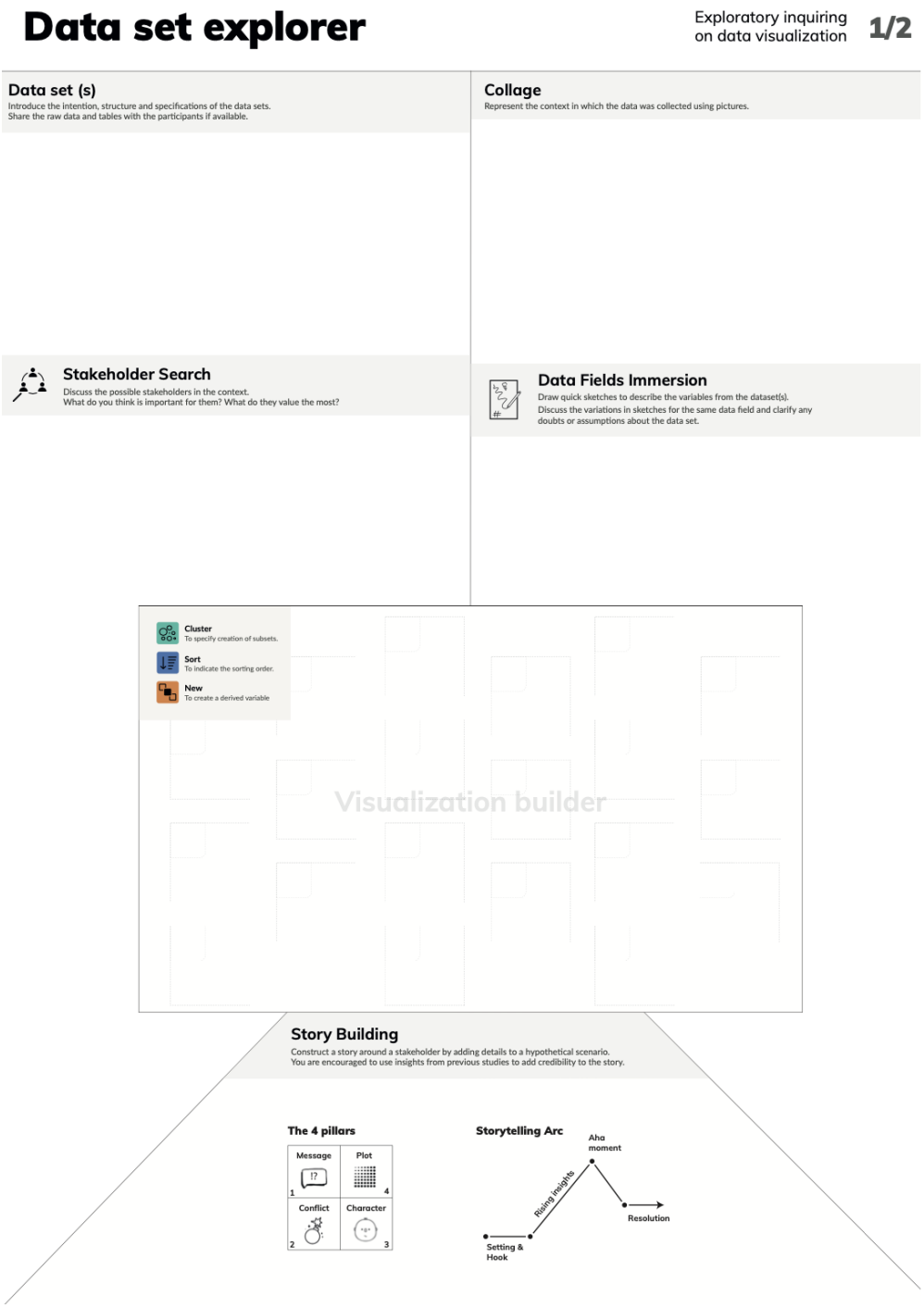
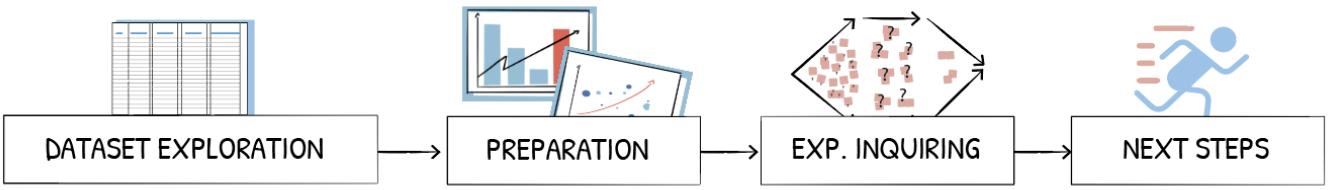


Figure 27: The canvas designed for the creative session- Dataset Exploration

Refined Procedure



Project Owner **Resource group (Ideally, 5-8)**

1

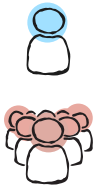
Creative session, Dataset Exploration

- Introduce the central question of the project and the goal of the session- To identify and suggest data visualisations to be made from the available quantitative data.
- **Introduction** Introduce the dataset and data fields that are going to be used for the session.
- **Warm-up** sketch out datafields that are most interesting to you and clarify assumptions if any.
- **Stakeholder search** Discuss and list the possible stakeholders in the scenario corresponding to the dataset and think from the stakeholder's perspective about what they would like to know from this dataset.
- **Storytelling** Construct a story to share your experience or previous knowledge relating to the topic of the dataset.
- **Visualisation suggestions** Discuss and use the 'visualisation specification canvas' to communicate the suggest
- **Reflect** Discuss on the activities carried out during the session, what worked and what could be improved.

2

Preparation of interactive visualisation

3



Creative session, Exploratory Inquiring

- » **Introduce** the participants to the central question, goal of the session, the dataset, and the visualisation created.
- » As a wam-up activity, start with a topic that interests the group and sequentially build a chain of questions one after the other.
- » **Diverge** In pairs, read, discuss, and analyse the visualisation. Note down insights in the form of questions that emerge from the activity.
- » **Reverge** Reflect on the questions posed in the previous activity, rearrange, and cluster them based on their conceptual meaning.
- » **Converge** Select the most interesting clusters/ questions and discuss the next steps that could be taken to address them.
- » **Reflect** Discuss on the activities carried out during the session, what worked and what could be improved.

4

Next steps

Refinements

This corresponds to the improvements made to the procedure upon the learnings from the previous iteration.

5.5.2 Execute

 **Project Owner**

 **Resource Group**

Project Owner

Vignesh Balakrishnan & company mentor

Resource Group

Five members of the SVC team participated in the first creative session (incuding the company mentor), and four participated in the second.

1  **Dataset Exploration**

Dataset used

ElaadNL open dataset and Ford internal dataset corresponding to the central question. All the datasets were aggregated in nature.

Introduction: 10 mins

The participants were introduced to the goal of the session- to examine the dataset and suggest visualisations to be made from them, to the central question “How can charging experience for electric vehicles be improved?” and the datasets themselves. Since the participants were not familiar with the context of this project, a brief introduction to the graduation project was also included as part of this activity.

Warm-ups: 10 mins

As a warm-up activity, participants were asked to pick interesting datafelds from the dataset and visualise on a sticky note. After that, participants were asked to discuss the possible stakeholers involved in the scenario.

Storytelling and Visualisation Specification: 40 mins

Participants were introduced to the visualisation builder section of the dataset exploration canvas and the tokens. They were asked to pick a stakeholder, construct a hypothetical story of a scenario around the context of data collection, and narrate to the rest of the resource group. This activity was done sequentially, that is one participant after the other. When the narration was taking place, the participants were asked to make use of the visualisation specification space in the dataset exploration canvas to suggest visualisations that they would like to be created for analysis.

2 Preparing the data visualisation

The Dataset Exploration Session helped them identify the value of combining the internal dataset used for this session with another available dataset. This activity required data wrangling, which the company mentor performed using Alteryx. During this period, we made a short call with a member from GDIA for clarifications regarding the same. Multiple visualisations in the form of line graphs, bar graphs, and heat maps were created. The company mentor handled the internal dataset, while the author handled the external dataset.

3 Exploratory Inquiring

Session set-up
In-person

Visualisation
Personal Computer

Workspace
White Board

Figure 28: Visual Representation of the set-up of creative session.

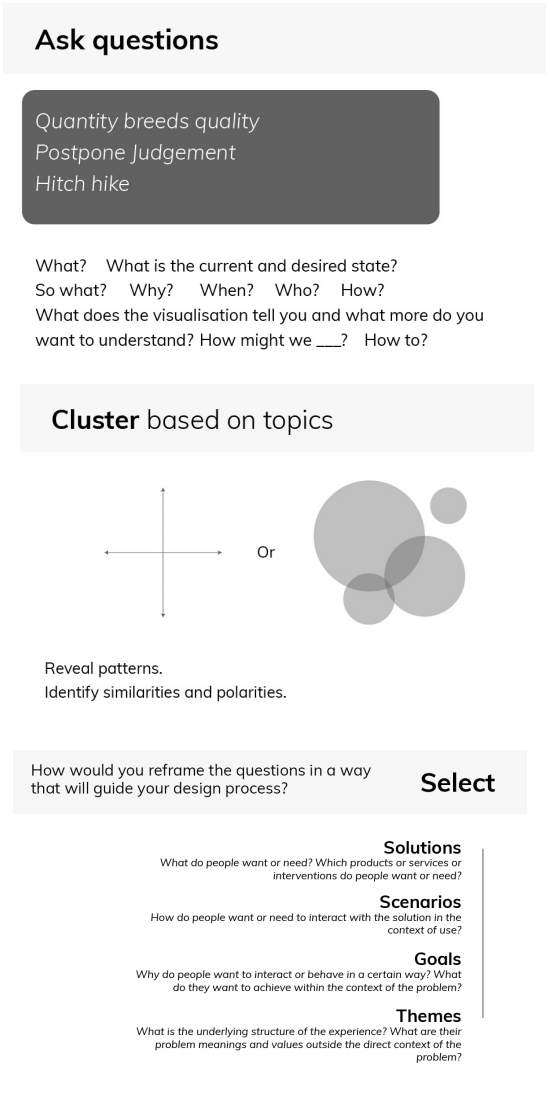


Figure 29: The printed sheets used in the creative session to inform about the activities, supporting the verbal instructions.

Introduction: 30 mins

The participants were introduced to the goal of the session- to generate insights on user behaviour and needs relating to the central question How can charging experience for electric vehicles be improved? Following that, the data visualisation was introduced one by one.

Diverge: 25 mins

Participants were asked to analyse the data visualisation and note down insights in the form of questions on (digital) sticky notes. The following tips were given to induce the diverging mindset required for this activity. *Be openly curious, postpone judgement, Quantity breeds quality, what would your stakeholder like to know?*

Reverge: 25 mins

Participants were asked to look back at the questions posted in the previous activity, and were asked to cluster them. They were allowed to reformulate the questions and even go back to the visualisation for clarifications.

Converge: 25 mins

Participants were asked to select the cluster/questions that they would like to follow up or explore further, and discuss how they would go about it.

Reflection

The participants and I collectively reflected on the activities from both the sessions, what went right and what could be improved.

5.5.3 Learn

L3.1 The first creative session allowed for preliminary examination of dataset

Reflecting on the outcome of session 1, most requests for desired data visualisation were outside the scope of directly visualising the available dataset. These include data fields that were either not part of the dataset used in the session, for example, Geographical data or data fields or not readily available with the current dataset. For instance, one such request was the need to visualise 'the pattern of distances driven between the charging events'. This suggestion led us to go back one step, get in touch with a member from GDIA, and search for datasets through which we can create this desired visualisation. However, they were located in two separate datasets and required pre-processing (wrangling) before they could be visualised.

> *"I would be happy if the variable charging point ID is rather (indicative) of where the charger is located." P4*

On the one hand, the activities part of this session was rather general and not specific to the available dataset, which led to suggestions that were outside the scope of the dataset brought into the session. However, on the other hand, the generalised nature of the session inspired participants to take a novel standpoint of viewing the same dataset and be inspired to explore further the possibilities without any restrictions. Although it is not directly aiding to the intended goal of the session, that is to suggest aspired visualisations, it helped us identify new data fields with, which can be considered when arranging a new data-gathering setup.

L3.2 There was a need for iteration on data visualisation inside the creative session.

Although the interactivity feature allowed the resource group to make immediate changes to the state of visualisations, some exploration directions demanded the creation of new visualisations, either direct or derivative, from the available data sheets. The insight into creating these visuals did not appear in the previous session- dataset exploration. Analysing the visualisations shed light on examining the dataset deeper by creating new visualisations, echoing the iterative nature of the explorative analysis.

Since we are dealing with novice data analysts', they could not quickly act upon these exploration directions by creating new visualisation on the fly. The need to have an external agent- either an analyst or a tool to support the resource group in this process is inferred by a participant's comment of needing a visualisation master.

> *"We need a visualisation master in the session... You know someone who can make a new visualisation instantly." P2*

> *"I would not have to find the data, it would be found for me." P1*

L3.3 Most questions fall under 'Deep reasoning questions' and 'need for further qualitative research' categories.

A total of 25 questions were noted on the sticky notes during the exploratory inquiring creative session. These questions were coded based on Eris's (2004) taxonomy, and the distribution was found to be ten low-level questions (40%), three Generative Questions (12%), and twelve Deep Reasoning questions (48%). Comparing this with the results of Study 3 from (Mellado Cruz, 2021), where she conducted a similar study with Ford SVC team members, a noticeable change was a decrease in the percentage of generative questions (from 21% to 12%). An argument that explains this observation is that the generative questions proposed in her study concerned the possibilities of creating new data visualisations. However, since the interactivity element in the current set-up allowed participants to quickly act upon some those questions and change the state of visualisation, these questions were not noted.

The deep reasoning questions mainly comprised of causal antecedants, that is, questions pertaining to 'Why something happened?". All of the deep reasoning questions were directed towards exploring the problem space to either add the why or contextualise the insights obtained from the data visualisation

It was found that the generative questions that were noted down did not emerge during the first activity- that is during the 'diverge' activity but started to surface only after reflecting on the questions during and the 'reverge' and 'converge' activity. Meaning, data visualisation directly gave rise to deep reasoning questions, while reflecting on these questions inspired the designers to formulate generative design questions.

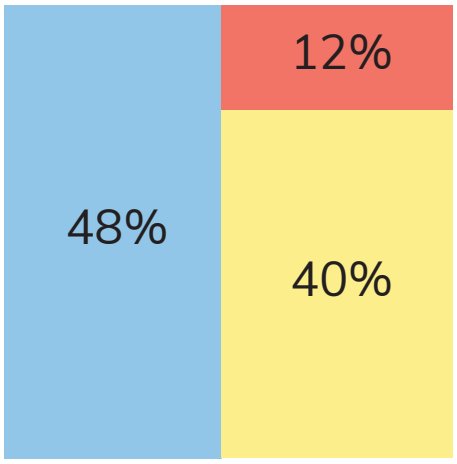


Figure 30: Distribution of questions based on Eris's (2004) taxonomy.

Example questions from the session:

Low-level:
Do short charges relate to more on-the go charges?

Generative Design Questions:
How to increase awareness of what's good for the battery?

Deep-reasoning:
Why are there changes (in charging behaviour) between months?

*There were several questions verbally exchanged between the participants while carrying out the activities. These questions were not taken into consideration for this analysis. Only the questions that were noted down on the sticky notes were analysed.

L3.4 Need to capture the source (visualisation) from which the question originated

An important aspect of sensemaking is to find patterns and connections between pieces of information. I observed that it was challenging for the participants to trace back the visual from which the question emerged to find reasons and relations to advance in the exploration. Participants indicated that they would like to capture and store the source of this information, that is, the visualisation along with the questions. This would allow them to trace back, compare and contrast the different questions along with the visuals during the reverging activity, thus strengthening the sensemaking process. One reason this challenge was not observed in the previous iteration could be the fewer visualisations used in that study (3). In this iteration, we use several data visualisations (10+) distributed across various spreadsheets, making it difficult to keep track of the source of the question. However, this setup depicts the actual use case much closer than the previous one, and is an important factor to consider when developing the final version of the tool (the deliverable).

> *" I would start from this (question), and then the other question pops up. Do we have an explanation for this and that, which leads to more follow-up questions? If we collected all of the different graphics (visualisations) and put them together, I could have all of the visuals together and can make sense of it. To come with reasons or more hints as what why this happend?" P1*

L3.5 Tokens were not actively used while suggesting visualisations

The dataset exploration canvas was designed to support the resource group in communicating visualisation suggestions. However, it was observed that the participants did not actively utilise the tokens to specify their suggestions. This could be due to lack of clarity on how to use these tokens as they were fairly new to them and there were not any examples provided as to how to use them. One other explanation for this could be they decided to use their tacit knowledge instead to communicate theie suggestions. Further research is required to confirm the observation.

L3.6 haring of insights and assumptions made while creating the data visualisation

At the time of creating the visualisation, the creator makes certain assumptions and also at the same time, generate insights about the dataet. In the current set-up, these are not shared and discussed with the resource group while introducing the visualisations. Although there is a possibility of fixation that is the information initially shared could have an influence over inquiring, it could provide a jumpstart for the participants to catch up on the results of initial analysis carried out by the project owner, and contribute in a more productive way.

L3.7 Preference in the 'form' of the tool used

There are three distinct types of tools that are used in creative sessions. Aguirre et al. (2017) classify them in three groups: readymade (for example, sticky notes), templated (business model canvas), and contextually designed (uniquely tailor-made activities which take into account the context of the participants in time and space). In this iteration, it was intentially decided to provide two variations of tools for the participants to carry out the activities of the creative sessions. For the dataset exploration session, a templated tool (dataset explorer canvas) was used and for the explorative inquiring session, readymade tools like sticky notes and printed sheets with tips for activities were used. Although the participants liked the idea of having a templateto guide them through the process, they prefered the readymade tools with printed inspiration sheets, as it provides more flexibility and ease of use.

5.4 Discussion

5.4.1 Role of facilitator

According to Heijne and van der Meer (2019), the role of a facilitator in a creative session is (A) To maintain role rigidity, (B) to maintain the group's energy level and (C) To provide background information about the topic of the collaboration. While facilitating the workshop with the members of the SVC team, I observed that the first two elements, that is, to keep them informed of their tasks/roles and the mindset towards achieving the goal, did not require much assistance. I suppose this is because the SVC team is familiar with participating in creative sessions and are well-versed with the creativity techniques, rules and mindset. At the same time, using data visualisation as an external stimulus in a creative session is relatively new to their workflow. The amount of contextual information (information about the data) that needed to be transferred to the group before they can understand, assimilate, and analyse the visualisations is profound compared to traditional creative sessions (where data from qualitative studies are used as source of information and inspiration). Also, we saw in Section 5.3.3 the need for an external agent to iterate, revisualise, and in general assist the group with data visualisation expertise during the exploratory inquiring session. These observations direct me to rethink the role of the facilitator when hosting the exploratory inquiring session or in general using data visualisation in creative sessions, from facilitating the creative process to supporting the exploration using data expertise.

5.4.2 Type of questions and their implications

From the question analysis, it was clear that the visualisation indeed inspired the participants to identify interesting areas to explore, especially in the problem space. The inclination to dive into the problem space, especially in the early stage of design, is in line with previous observations of the design process in expert designers (Lloyd & Scott, 1994; Lawson, 2004).

The analysis also showed a recurring deep reasoning questions during exploration and a mixture of deep reasoning and generative questions further into the session- that is during and after the 'reverge' activity. A plausible explanation for this observation is that data visualisation, as an analytical tool (Munzner, 2014), gives rise to deep reasoning questions. The deep reasoning questions were mainly causal antecedents, a category of questions where the designer wants to know the states or events, that have in some way caused the concept in question (Eris, 2004). These questions indicated the need to explore the problem space, specifically to calibrate and contextualise the insights obtained from the analysis. Calibration here refers to verifying the facts presented in the information to build trust with the information that one acquires from visualisation, and contextualisation refers to the inquiry into external factors that could have affected the measured parameters. For example, in the question, 'Why are users doing so many short charges?', the

designer observes that the user is doing short charges and wants to know what could have been the factors that influences this behaviour.

On the other hand, generative questions surfaced only during or after the 'reverge' activity. All the three generative questions that were formulated correspond to the "Method generation" category, which resembles a typical design problem statement. Method generation questions are a sub-category of generative design questions that has a completely known initial question concept and multiple possible and completely unknown secondary question concepts. For example, let us take the following question "How to increase awareness of what's good for the battery?". The origin of this question comes from the premise that the user is not having a charging behaviour that is good for the battery. Here, the prior knowledge with the resource group about what is good for the battery and the fact derived from the data visualisation that the user is not having this behaviour, leads them to identify an opportunity for intervention to improve the user experience. By posting this question, the participants expresses the presence of the primary question concept and also the need to explore the secondary question concepts.

My view on this observation (generative questions emerging during the reverging activity) is that the interpersonal interactions among the group during this period facilitated discussion on the topic and eventually led to the formulation of method generation questions. Meaning there was consent among the group that the insight gathered from the visualisations corroborated their existing knowledge of the topic, increasing confidence with the observation from data visualisation. These two observations direct me to speculate that trust and confidence play an essential role in incorporating the insights from the data visualisation into the design process. Therefore, iterating (inside and between exploratory inquiring) will help increase trust and produce more generative questions in the form of problem statements. However, this needs further research and the details of which are briefly discussed in Section 6.3.

5.4.3 Working medium

Designers in practice seem to prefer the analogue set-up for brainstorming and ideation (Palmer, 2019). This inclination was observed and later confirmed in the reflection interviews that the SVC members also have a similar opinion. Nevertheless, they still consider online media beneficial because of their ease, flexibility, and convenience and the familiarity they gained with the digital whiteboard tools over the last few years. I went back to the literature to search for previous works done in this area that can support these observations and possibly why one medium works better. A recent study (Frich et al., 2021) suggests that a digital set-up is more conducive to convergent thinking. They speculate that this could be due to the information density

and overview participants get in the digital medium. Having a large number of notes and, on average more information on each note than handwritten notes mean that participants are exposed to more initial ideas that they can build on and make an informed decision during convergence. We have good reason to extend this hypothesis for the 'reverge' activity, where it is also essential to have an overview of all the ideas (in our case questions) to find connections between them and move forward in the sensemaking process. In addition, a digital working medium offers more accessible long-term storage, management, and retrieval of ideas compared to an analogue set-up. Therefore, with reasonable certainty, I recommend using a digital working medium for the creative sessions as part of the Data Interrogation method.

5.4.4 Co-located or distributed

Isenberg et al. (2011) divides collaborative visualisation into two axes; one based on location (Co-located and distributed) and the other based on the temporal domain (synchronous and asynchronous). In my study, all the iterations followed a synchronous set-up, meaning all the collaborators contributed simultaneously. I chose this to tap into the social interaction component of working in groups and a typical way creative sessions take place in the design field. On the other hand, the first iteration occurred online (distributed), and the others happened in person (co-located). In the first iteration, I could not gather any meaningful insights about the set-up (other than the issue to view multiple windows simultaneously) due to its negative influence on the process. Hence, due to lack of deep insights into the different modes of set-up used to conduct the creative sessions, it is difficult to draw strong conclusions on the most suitable setup to be used. However, since co-located medium offers room for implicit communication (Pinelle et al., 2003) and is more conducive to interpersonal interaction, it augments creativity in such active environments. However, it requires further study to develop a solid argument to justify one over the other.

5.4.5 Happy accident: Aggregated data to personal data

The dataset exploration session required only the meta data of the dataset and not the actual data itself. The session facilitated the resource group to investigate the usefullness of the dataset without the need to intervene into personal details of the users which by itself is an advantageous point of the method. This relieves the burden of designers to gain restricted access into such files for the sole purpose of preliminary exploration.

5.4.6 Evolution of requirements

At the beginning of the design iterations, I set out certain requirements for the concept method derived from the learnings from the literature. However, only when attempting to execute and test the concept was I able to identify the practical difficulties and additional requirements needed for the method. The learning-by-doing aspect of my design process helped evolve requirements and contributed to the iterative improvement of the concept.

Iteration #	Key learning
1	Pre-examination: Need to involve the resource group in deciding what visuals need to be made.
2	Modality: Need to provide direct access to the visualisation tool.
3	Visualisation gives rise to deep reasoning questions. These questions when reflected, results in generative design questions.

Table 2: Summary of thekey learnings from each of the iteration.

6

Deliver

In this chapter, I first present the final concept- Data Interrogation, which will be the deliverable of this project. The final concept is named as such, because it clearly captures the essence of the method- to systematically generate insights from data using the power of questions. The deliverable, The toolkit consists of two subparts, an informative Booklet and two canvases (A) Dataset Exploration Canvas (B) Exploratory Inquiring Canvas. Following that, I conclude this project by discussing the implications, limitations and future recommendations.

6.1 Introducing the tool

The inspiration for this project rooted from the work done by Mellado Cruz, 2021, wherein, I aimed to bridge the gap between the theoretical understanding and the practical application of the technique exploratory inquiring on data visualisation. In the initial research on the context and literature, I identified three potential opportunities out of which I chose, conceptualising exploratory inquiring as a design method. With the help of the preliminary design iterations, new challenges pertaining to using data visualisation in creative sessions were discovered and progressively tackled. The final concept, delivered in the form of a design method acts as an intervention that allows and encourages the SVC team to systematically derive insights from thin data using the power of questions.

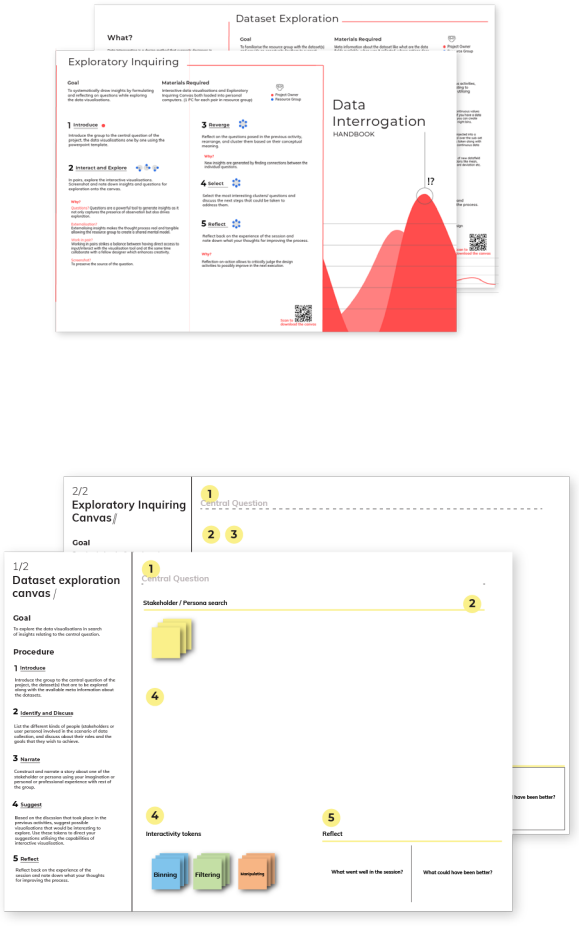


Figure 31: Deliverables: Informative booklet and canvas.

Booklet

This is the first part of the deliverable. Here, I visualise and elaborate the background information of that one needs to know to be informed (and convinced) about the use of the method 'Data Interrogation' in their design projects.

Canvasses

The second part of the deliverable consists of two canvasses, one for each of the creative sessions. These act as a tool designed to be used as an intervention to support the creative sessions. The first canvas corresponds to the Dataset Exploration session and the second Exploratory Inquiring. The tool aims at creating a structured workflow of the creative sessions.

6.1.1 Booklet

Goal

The goal of this booklet is to transfer knowledge about the method 'Data Interrogation' to the intended users- SVC team members. It acts as an informative document, consisting content for four elements which are necessary to carry out a design method (Daalhuizen & Cash, 2021) namely, Goal, Procedure, Rationale, and Framing. The goal and procedure corresponds to the internal structure of the method, while rationale and framing correspond to the contextual positioning of the method use, both of which are essential components of method use.

In this booklet, I provide the reasoning based on which the overarching concept: the two creative sessions were proposed (at a macro level) and the individual activities inside the creatives sessions (micro level). I am including the micro decisions that led me to choose the individual activities as part of the creative sessions with the goal of providing flexibility to the user. It provides an opportunity for the method user to replace or supplement the suggested activity with other creative techniques. In addition, I also include some tips and best practices from practice that were not developed or tested as part of the studies of this project, but is included (with references to the original sources) to assist the designers in preparation for the creative sessions.

Figure 32: Mock up of the Booklet.

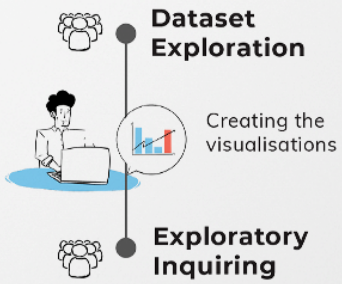

Data
Interrogation
Booklet
Scan to download the canvas
Materials Required
Interactive data visualisations and Exploratory Inquiring Canvas, both loaded into personal computers.
3 Reverge
(30 min)
Reflect on the questions posed in the previous activity, rearrange, and cluster them based on their conceptual meaning.
Why?
New insights are generated by finding connections between the individual questions.
4 Select
(30 min)
Select the most interesting clusters/ questions and discuss the next steps that could be taken to address them.
5 Reflect
(10 min)
Reflect back on the experience of the session and note down what your thoughts for improving the process.
Why?
Reflection-on-action allows to critically judge the design activities to possibly improve in the next execution.
Work in pairs
One after the other
All together
Project Owner/Facilitator
Resource Group
Questions are a powerful tool to generate insights as they capture the presence of information and drive exploration.
Externalising insights makes the thoughts real and tangible that can be discussed with the rest of the group and contribute to creating a shared mental model.
Work in pairs strikes a balance between having direct access to input/interaction with the visualisation tool and, at the same time, having a social interaction element that enhances creativity.

What?

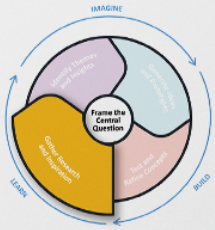
Data Interrogation is a design method that supports designers in discovering insights from thin data (data without much contextual information), for example, in-vehicle sensor data.

It is founded on three powerful concepts: collaboration, visual exploration and question-asking to systematically generate insights from data visualisation to inform and inspire the early design process.

It consists of two collaborative creative sessions, Dataset Exploration and Exploratory Inquiring, which are explained in detail.



When to use?



The method was developed to be used during the early stage of the design process to identify user needs and directions of exploration. Although, with minor adjustments, it could also be used during the other phases.

Dataset Exploration

Goal

To familiarise with the context of dataset(s) and suggest visualisations to make with the potential to deliver insights.

Mate

Meta-
data f
and w

1 Introduce

(10 min)

Introduce the group to the central question of the project, the dataset(s) that are to be explored along with the available meta information about the datasets.

2 Identify and discuss stakeholders

(30 min)

List the different kinds of people (stakeholders or user persona) involved in the scenario of data collection, and discuss about their roles and the goals that they wish to achieve.

Why?

Thin data inherently lacks contextual information. Discussing the people involved in the situation will make you think about the people and other contextual factors involved.

Project Owner/Facilitator
Resource Group

All together

Figure 33: Mock up of the Booklet. View: Unfolded front side.

Scan to download the canvas

erials Required

data about the dataset like what are the ields available, when was it collected, what hose ations does the data represent etc.

3 Narrate

(30 min)

Construct and narrate a story about one of the stakeholder or persona using your imagination or personal or professional experience with rest of the group.

Why?

Storytelling is a powerful tool to convert abstract concepts into concrete, tangible forms. Narrating a story will allow you to broaden your perspective and create a life around the data.

4 Suggest

(30 min)

Based on the discussion in the previous activities, suggest possible visualisations that would be interesting to explore. Use the tokens to direct your suggestions and give specific

Work in pairs — One after the other

5 Reflect

(10 min)

Reflect back on the experience of the session and note down what your thoughts for improving the process.

Why?

Reflection-on-action allows to critically judge the design activities to possibly improve in the next execution.

Tokens

Use this token to group several continuous values into smaller "bins". For example, if you have a data field that denotes the day's time, you can create morning, afternoon, evening, and night bins.

Filtering allows limiting the data injected into a particular chart, giving you control over the sub-set of data used to visualise. Use this token along with categorical data fields or binned-continuous data fields.

Use this token to specify creation of new datafield by arithmatic or statistical operations like mean, median, mode, summation, standard deviation etc.

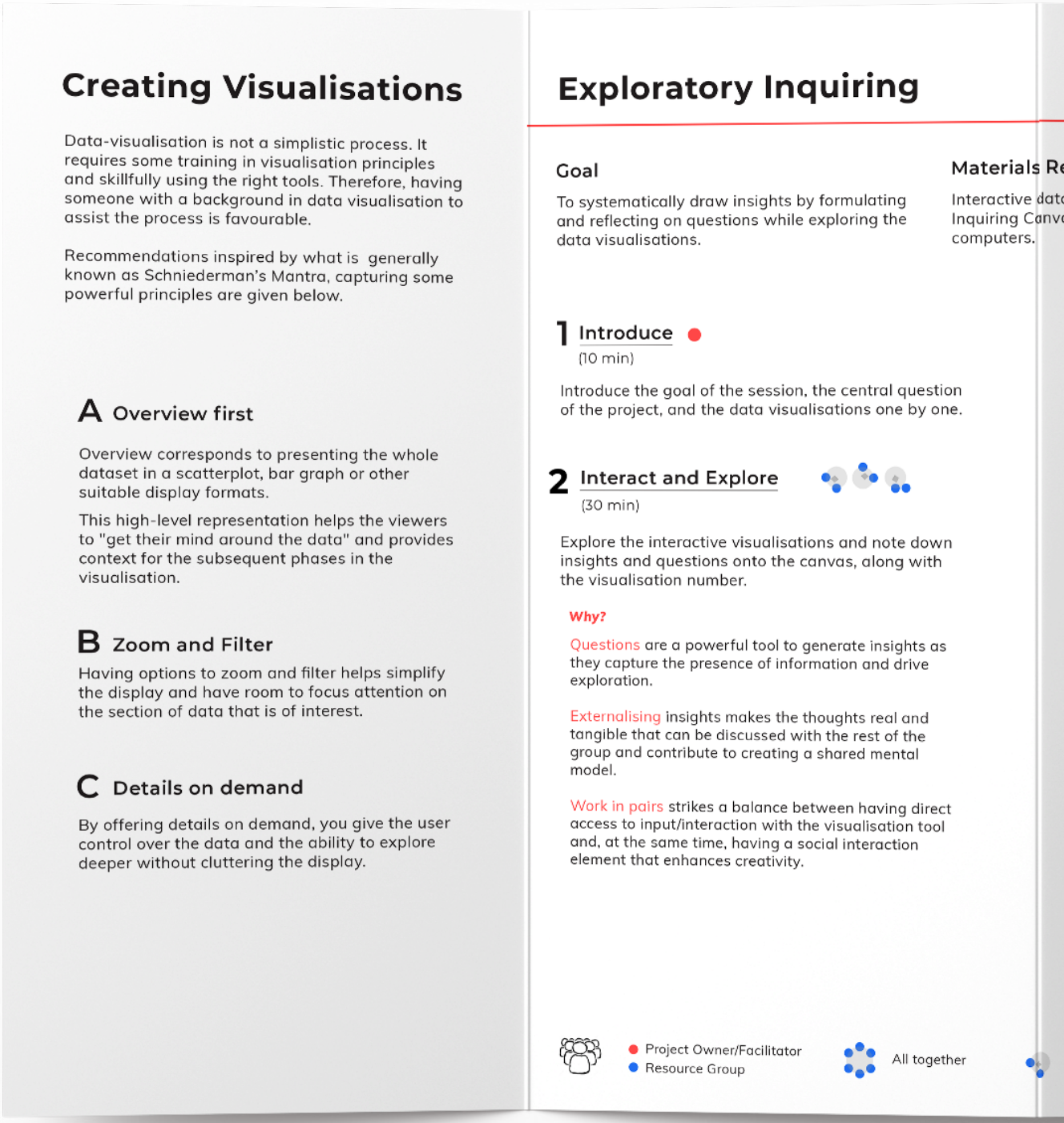


Figure 34: Mock up of the Booklet. View: Unfolded back side.

Scan to download the canvas

equired

a visualisations and Exploratory
as, both loaded into personal

3 Reverge

(30 min)

Reflect on the questions posed in the previous activity, rearrange, and cluster them based on their conceptual meaning.

Why?

New insights are generated by finding connections between the individual questions.

4 Select

(30 min)

Select the most interesting clusters/ questions and discuss the next steps that could be taken to address them.

5 Reflect

(10 min)

Reflect back on the experience of the session and note down what your thoughts for improving the process.

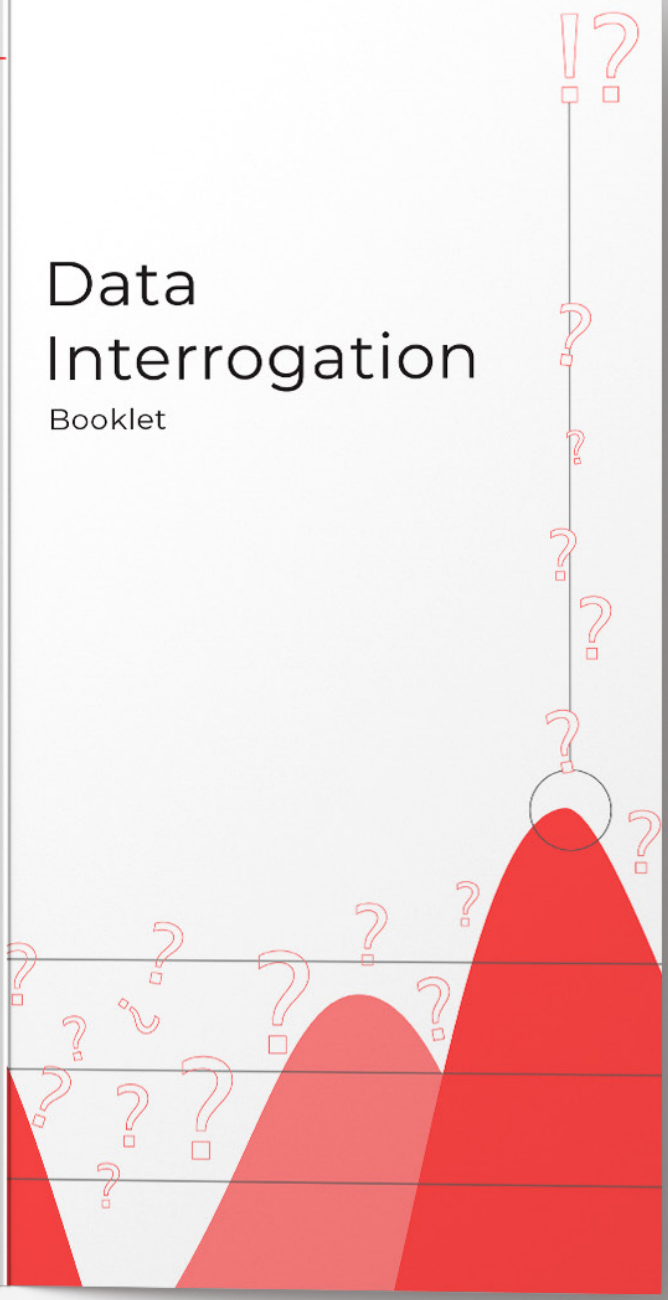
Why?

Reflection-on-action allows to critically judge the design activities to possibly improve in the next execution.

Work in pairs — One after the other

Data Interrogation

Booklet



6.1.2 Canvasses

Goal

The goal of the canvasses is to provide a tangible working medium for carrying out the different activities part of the creative session. It acts as an extension to the mental space, to create a shared view on the outcomes of the activities.

In the first session, the goal is to explore the dataset and provide suggestions for possible visualisations while the second session focuses on making valuable interpretations from the data visualisations.

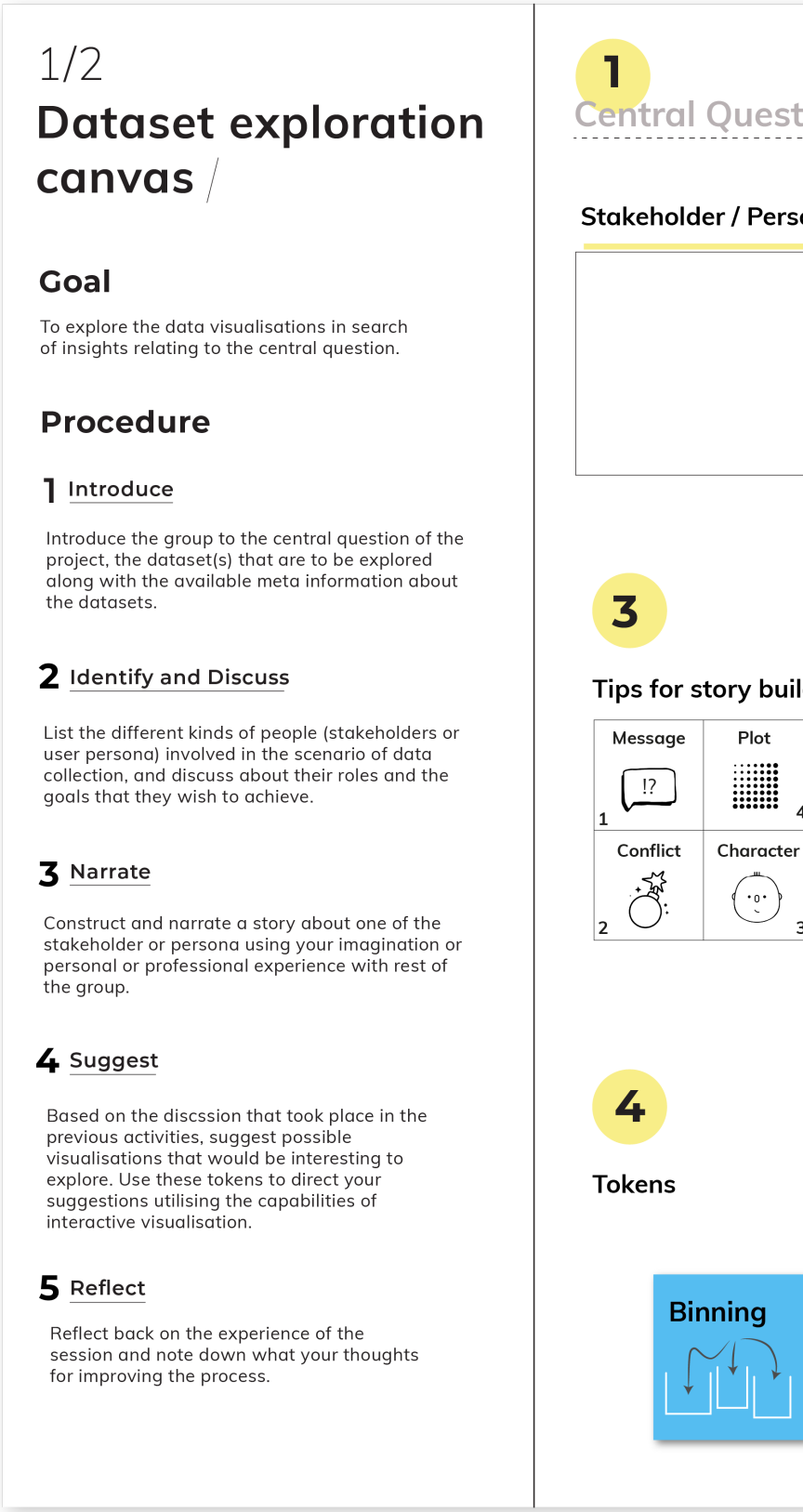


Figure 35: Dataset exploration canvas

ion

ona search

2

ding

Filtering

Calculations

+ - &

5

Reflect

What went well in the session?	What could have been better?

2/2

Exploratory Inquiring Canvas//

Goal

To explore the data visualisations in search of insights relating to the central question.

Procedure

1 Introduce

Introduce the resource group to the central question of the project

Introduce the data visualisations one by one using the powerpoint template.

2 Interact and explore

Split the resource group into pairs (Preferably each with at least one who is familiar with the visualisation tool used)

Explore the data visualisation using the interactive features along with your partner.

Note down the interesting observations and questions in the canvas.

3 Reverge

Regroup and reflect on the questions posed in the previous activity, rearrange and cluster them based on their conceptual meaning.

4 Select

Select the most interesting clusters/questions and discuss the next steps to address them.

If it belongs to the problem space, formulate a research question that could inspire future studies.

Formulate a problem statement if the selected option directs to exploration in the solution space.

5 Reflect

Reflect back on the experience of the session and note down what your thoughts for improving the procedure.

Reflect on what worked and what could be improved.

1 Central Question

2 3

1

5

9

4

Key takeaways

Figure 35: Datas

Figure 36: Exploratory Inquiring canvas

2 3 4

6 7 8

10 11 12

set exploration canvas

5

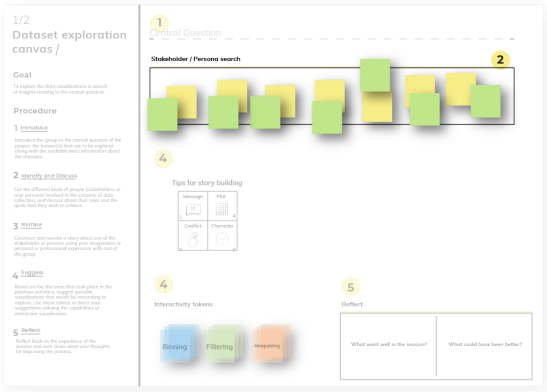
Reflect

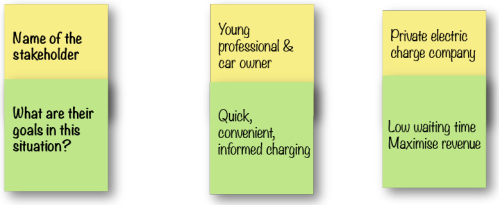
What went well in the session?	What could have been better?

6.1.3 Canvas in action

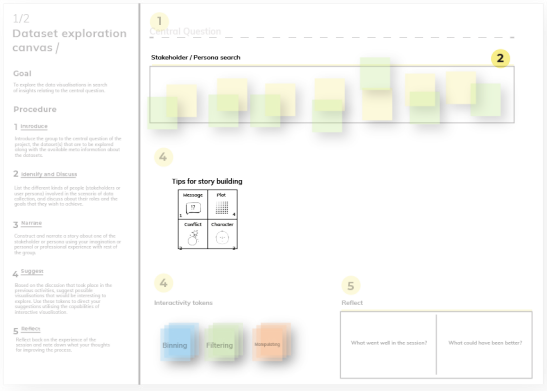
Dataset Exploration Canvas

The work in the canvas starts once the project owner has already completed introducing the goal of the project, goal of the session, and the dataset to the resource group.

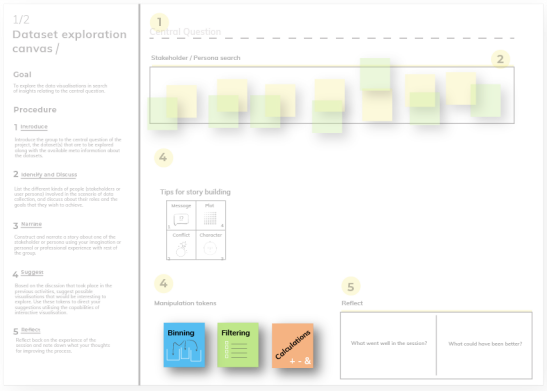


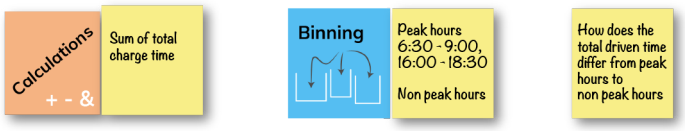


In the first activity, resource group lists out the possible stakeholders and their goals in the scenario, based on their curiosity.



Now, they pick out a stakeholder or a persona of interest, build, and narrate a story using the tips provided. This would also be an opportunity to add more curiosity questions. For example, an electric charging company would want to know what time of the day has the most demand for charging.

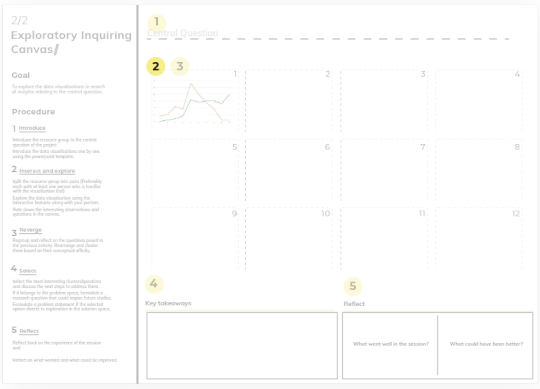




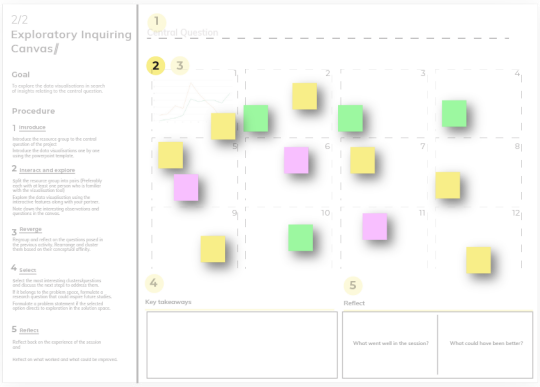
Finally, they suggest possible visualisations to make that can potentially yield insights into the required question. The tokens aid in easy communication of manipulations that needs to be done with the data.

Exploratory Inquiring Canvas

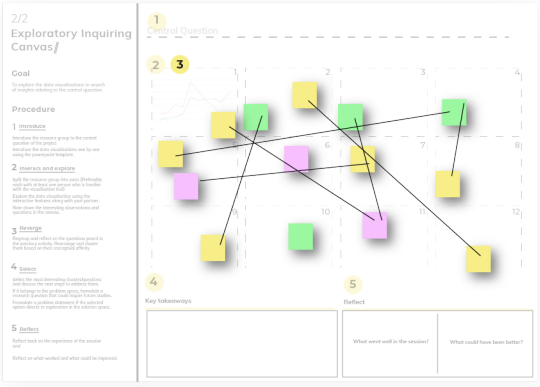
This canvas offers a ground for the resource group to externalise their observations and insights derived from the visualisations.



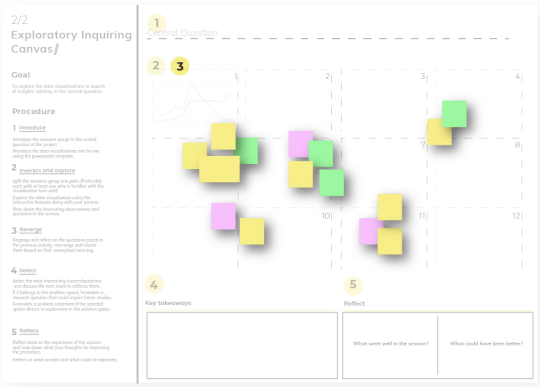
Before the session, the project owner prepares the visualisations, numbers them sequentially, and places a screenshot of them on canvas. It is important to number the visualisations as it would help preserve the source of the insight.



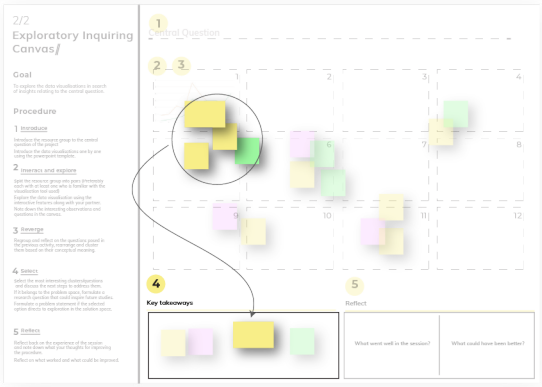
During diverging, the resource group explores the visualisations in pairs and notes insights on the respective screenshots on the canvas. When doing so, it is crucial to mark the visualisation's number along with the insight as these cards would be rearranged in the subsequent activities.



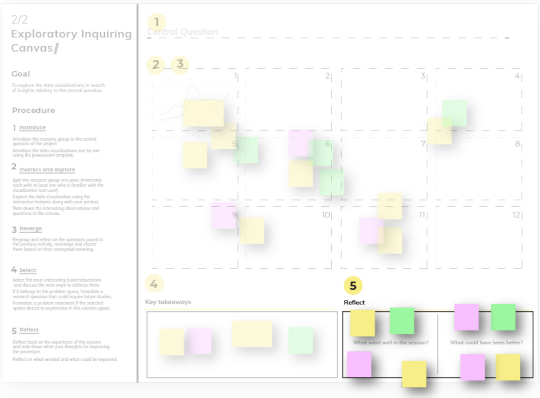
In the reverge activity, the resource group collaboratively discuss and find connections between the posted insights and possibly generate new insights during the activity.



Now, the canvas becomes independent of the visualisation screenshots, and the resource group rearranges and clusters the insight cards (sticky notes). As these cards have the visualisation number written on them, it would be easier to locate (if needed) the source of the insight.



As a penultimate activity, the resource group select their most promising insight or cluster, and drop them (re-formulate if needed) them in the key takeaway box. This would give the project owner tangible and actionable insight to act upon after the session.



As a penultimate activity, the resource group select their most promising insight or cluster and drops them (re-formulate if needed) in the key takeaway box. This would give the project owner tangible and actionable insight to act upon after the session.

6.2 Implications

6.2.1 Relevance for Ford

A. Awareness

It is known that designers often work in groups and same is applicable for the members of the SVC team (Section 2.3). However, using data visualisation inside a creative session as an external stimulus is relatively new and is not widely researched before. In my view, the value of the project does not lie only with the final deliverable, but is contained in the process that starkly highlights the challenges which are encountered in executing group exploration with data visualisations. Thereby, the project creates awareness about the value of thin data to support design research, provides a systematic procedure and, a toolkit to execute such creative sessions.

B. Boundary Object

Star & Griesemer (1988) discusses that a boundary object is an article that is robust enough to communicate a common meaning, while at the same time, flexible enough to allow people to add their own interpretations. The final deliverable of this project serves the purpose of being a boundary object for Ford designers to initiate the use of thin data in design research for their future projects. The fidelity of final deliverable prescribes one way of executing exploratory inquiring while at the same time allows for continuous evolution upon repeated use. (Schønheyder and Nordby, 2018).

D. Connecting other URP works done in the methodology area

As mentioned in the first chapter, there were several other graduation projects that were carried out to support the data-enabled design at the Ford SVC team. The method- Data Interrogation acts as a bridging piece that connects these works (figure), giving Ford a comprehensive set out of tools and methods that they can utilise to incorporate data throughout their design process.

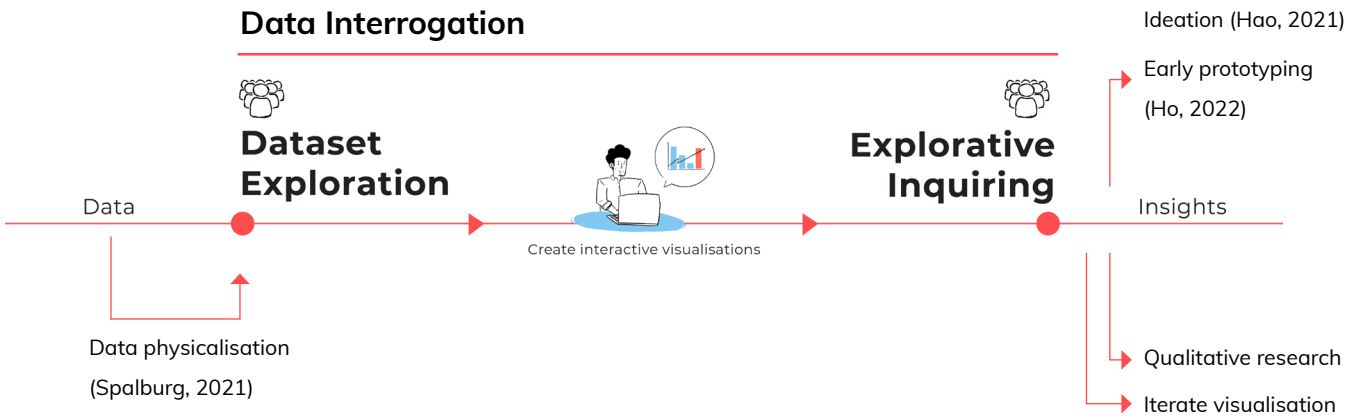


Figure 37: Illustration depicting where Data Interrogation fits with other URP works in the methodology are

C. Reason to request personal data

In addition to sensitising the resource group to the dataset and providing them with an opportunity to suggest visualisations, the session also proved useful in addressing another important challenge. The GDPR data privacy regulations set out strict policies for handling user data, wherein the data is protected from any use other than its intended purpose. Since for us to conduct the dataset exploration session, we only needed the meta-information about the dataset, and not the actual data itself, it provided a path for a preliminary examination to identify potent visualisations that lead to further exploration. Staying at this level of abstraction allowed us to reflect on what potential insights are contained in the dataset and simultaneously comply with the privacy regulations. This unintended outcome of my design process opens up an avenue for using user data for exploratory purposes.

6.2.2 Implications beyond Ford

Data interrogation is developed to be a context independent design method. Although, it was developed within the scope of the Ford design team, any large organisation with a similar need for design process can employ this method. With minor adjustments and improvements in procedure, these creative sessions can even be made applicable to other design projects with fewer resources.

The use of data visualisation as an external stimulus in creative sessions is not extensively explored prior to this project. Dove and Jones (2014), investigated the applicability of data visualisation to stimulate creative thinking by generating insights in the development of new products. My studies brought to light some of the major barriers faced by designers who are not data experts, which can inspire research in lines of making novice visualisations tools.

6.3 Limitations and Recommendations

6.3.1 Related to design iterations

(Not a) controlled study

The studies carried out as part of design iterations were formative. The goal of each study was to observe how designers carry out the procedure, reflect on the challenges they faced, and test the (presumably) improved version of the creative session in the subsequent iterations. Consequently, several factors varied between the studies (for example, the datasets used, participants, their expertise, mode of interaction with the visualisation, and working medium). The variability in all components of the research and the inherent inconsistency of the system prevents drawing concrete conclusions. This could be overcome by conducting future studies where isolating mechanisms (a way by which the test component is varied and the rest is kept constant) can be used to find the individual effects of each component on the net outcome of the method.

On the other hand, to understand the impact of the method and to evaluate whether and in what ways the tool was useful, longitudinal studies that closely resemble the context of the SVC team's day-to-day working maybe studies. This would allow us to observe the evolution of method use, that is, how the designers adapt the method upon repeated use and also support in increasing ecological validity. While this may provide a more realistic representation of real-world behaviour, it may also be subject to more variability and noise.

Analysis of questions

The participants exchanged several questions as part of their discussion when carrying out different activities of the creative sessions. However, they only noted the ones they found relevant for exploration. For example, they did not note down the questions that were possible to act upon by interacting with the visualisation or getting clarified by a fellow designer. Hence, these questions were not taken into consideration for question analysis. The study setup used here did not allow us to understand in finer details on how the interpersonal communication has an effect on the question asking process during exploration. Further studies that employ techniques like protocol analysis that can potentially be used to extract details such as patterns from unstructured conversations during the creative session.

Benchmarking of visualisations

The visualisations used for creative sessions were created by the author and the company supervisor (for the third iteration). The quality of any visual analysis relies on two factors. “What data is visualised and how the data is visualised”. Although our expertise level concerning data visualisation resembles that of the SVC members, these visualisations were not inspected or benchmarked to check for errors and maintain a uniform standard. In order to improve the quality of the research, the visualisations can possibly be evaluated and benchmarked by an expert to maintain consistency across different studies.

On a practical note, Ford designers can collaborate with GDIA members to seek assistance and feedback prior to taking the visualisation to the creative session. Getting feedback from an expert would ideally help rectify basic mistakes and possibly improve the quality of the visualisation. This helps avoid waste of time clarifying questions about visualisation and directly diving into analysis when meeting for creative sessions.

(mini) Creative Sessions

As a consequence of participants availability, it was only possible to conduct mini-creative sessions that lasted for about an hour. However, the creative sessions carried out within the SVC team usually span an entire day. Allocating an entire day for a creative session provides room for iterating the visualisations within the session and even the possibility to combine with other creativity techniques, in which case, the resulting output may vary. By conducting extensive (day-long) studies on Ford designers employing this method in one of their ongoing projects, we would be able to extract information on practical scenerios.

Evaluation of the toolkit

In ideal case, the final toolkit would have been presented and evaluated with the target group at the end of the project. However, due to the project’s time constraint, this evaluation study was not conducted. Method content theory (Daalhuizen & Cash, 2021), offers a detailed protocol (a questionnaire based on set of content variables, and associated scales) to evaluate and validate a design method. Follow up study can be conducted with the SVC designers, reproducing this protocol to observe the operational utility of the method in terms of efficacy and effectiveness. A sample questionnaire that could be potentially used to carry out such study is included in the appendix.

6.3.2 Discarded opportunities

The following part talks about the opportunities that were not followed up on due to limitations in the scope of the project and the expertise of the author. These are interesting avenues that future researchers of design methods could explore within the topic of exploratory inquiring on data visualisations.

Techniques for triggering specific types of questions.

We saw that certain types of questions correlate to high design performance depending on the phase in the design process where it is being used. That is, Generative Design Questions are more favourable for diverging phases, and Deep Reasoning Questions are favourable for converging phases in the design process. One of the directions that were briefly explored was how can asking these specific types of questions be encouraged when exploring the data visualisation based on the purpose of analysis.

Future researchers could explore implicit ways to create a conducive environment for the designers that foster them to ask DRQ or GDQ questions depending on the purpose of analysis. A point of caution is that the intervention needs to be implicit in nature as it shouldn't affect the fluent, opportunistic search of exploratory analysis.

A software tool that can assist designers when they are exploring data vis.

When conducting design research for a project, Ford designers carry out several research methods and perhaps multiple rounds of iterations, and exploratory inquiring is one of them. They need to use the data from these studies to gain a better understanding of the context, to draw a better picture of the current situation, and to navigate through the problem space. This inspired me to consider the opportunity of how might we centrally store and manage insights originating from different studies of the project. In my brief ideation, I conceived an initial concept for this opportunity- A digital tool with some degree of intelligence, that can provide additional information relevant to your line of questioning fetched from other studies or a data corpus. The novel data visualisation tools, for example, Snowy (Section 3.1) provide a better experience in terms of usability in creating desired visualisation, corresponding to the bridge between the mental and computational space. However, it would be beneficial to explore tools that can offer additional support to the insight generation process, which in some way can augment the analysis process, acting as an extension to the mental space.I did not follow up on this because of the scope of this project. However, it is a concept worthwhile exploring with additional resources and a bigger team of software developers and design researchers.

6.3.3 Other recommendations

Data interrogation as a participatory or co-design method

In the current version, data interrogation takes place only among designers but the body of study in the topics of participatory design or co-design talks about the importance of involving the users directly in the designing process. A direction worthwhile to explore is how can the users be involved in the creative sessions to gain their perceptive on the visualised data.

Combining data interrogation with qualitative design research methods:

Data interrogation can be either preceded or followed up with qualitative design research methods. In the first case, it is reasonable to assume that the insights from qualitative methods can channelise the nature of asking questions. While, when followed after, the qualitative studies can be used to contextualise or calibrate the insights derived from the data visualisations. Though these are very important aspects to consider when practically employing data interrogation in actual projects, these were not deeply explored by me due to the scope of this project. Follow up studies can be conducted to in order to understand in depth on how can Data Interrogation can benefit from qualitative design research methods.

Hardware

There are several possibilities to implement co-located collaborations, including, ConnecTable system, an interconnected individual displays (Tandler et al., 2001) or large, interactive and single-display technology such as display walls and tabletop displays (Tang et al., 2006). However, in the scope of this project, I only used the resources readily available to the SVC team, such as single-user displays like personal computers, laptops, and large screens in conference halls in my studies. My studies showed that mode of engagement plays a significant role when using data visualisation for creative sessions. I learnt that by giving participants direct access to input/interact with the visualisation tool to exchange information/action, we weaken the barrier for exploration. Therefore, I suggested using personal computers over large screens in conference hall as the latter offers a more accessible mode of interaction. It would be valuable to explore how the display hardware that allows multi-user input and a large screen size like tabletop displays will influence the collaboration.

Software

In order to accommodate shared attention and, at the same time, give the individuals direct access to interact, visualisation tools that allow for multi-user input would be ideal. However, considering the resources available and familiar to the SVC team- Qlikview and Excel are considered the most relevant. Excel is the most familiar tool to SVC designers and offers a convivial solution to visualise and analyse thin data. However, it can become tedious to manually capture screenshots when handling large amounts of data which requires multiple visualisations. I used Tableau, a program similar to Qlikview (data visualisation used within Ford) tool as the visualisation tool because the latter was not available for public access. With my brief internet search I was able to identify a feature named “Creating a snapshot with a note”. This precisely does the same function as discussed in the previous section regarding preserving the source of information. However, I could not explore and test the tool with my method and could not give a strong suggestion at this point.

6.4 Reflection

The project has reached its end, finally. This section corresponds to my personal reflection, highlighting some of my critical learnings in the journey.

Data and Visualisation

It is an undisputed fact that proficiency in working with data is a fundamental skill of a 21st-century professional irrespective of the domain. One of the learning objectives that I set out for myself at the beginning of the project was to gain theoretical and practical knowledge on the fundamentals of data and Visualisation. Reflecting on the journey, I am content with how much I was able to improve my skills in this regard, and my key takeaway is that there is a lot more than what meets the eye.

Expectation management

Collaborating with a large organisation like Ford for my graduation project, I believed my biggest struggle would be satisfying both the practical and academic expectations. Not taking anything away from these two, I realised that the personal expectations that I had regarding the project and the outcome were sometimes over-ambitious and beyond the scope of a graduation project. The bi-weekly coaching sessions with my university mentors and weekly meetings with the company mentor were immensely helpful as they offered constructive feedback on my thought process and, most importantly, guided me to stay on track and stay grounded.

Learning by doing

During the course of the project, I had to wear several hats for different activities, such as a designer, researcher, facilitator and, at times, data analyst. I enjoyed performing the creative tasks much more than the analytical ones. This helped me identify where I want to position myself as a design graduate when I kickstart my professional career.

Design process

At the beginning of the project, I had a well-thought-out plan and course of action. However, in reality, the project took several turns due to new discoveries and also external circumstances. This meant I had to adapt my planning and expectations continuously. I learnt some valuable lessons regarding the organisation aspect of a design project and being flexible to tackle the new challenges that keep sprouting on the go.

Wellbeing

This project has been a valuable learning experience for me professionally and personally. As a person and as a designer, I thrive in collaborative environments. I enjoy working in groups, bouncing off and building on each other's ideas. Taking up an assignment of this scale and working individually on a creative task, this project was indeed the most challenging test that I have faced in my life. This journey made me aware of my strengths and weaknesses and, most importantly, taught me about setting realistic goals and seeking support from people dear to me when necessary.

Documenting the reasoning

Being an individual project that lasted several months, I realised some ideas were lost in time, and it was difficult to track back to find justifications. One of the major takeaways from my experience with this project is to maintain a personal log of all the ideas and the reasoning behind them throughout the design process.

7

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8

Graduation Brief

DESIGN FOR our future

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy".
Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Balakrishnan
initials: V given name: Vignesh
student number: 5317436
street & no.:
zipcode & city:
country:
phone:
email:

Your master programme (only select the options that apply to you):

IDE master(s): ( ) IPD ( ) DfI (x) SPD
2nd non-IDE master:
individual programme: - - (give date of approval)
honours programme: ( ) Honours Programme Master
specialisation / annotation: ( ) Medisign
( ) Tech. in Sustainable Design
( ) Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: Milene Guerreiro Gonçalves dept. / section: DOS
** mentor: Senthil Chandrasegaran dept. / section: DOS
2nd mentor: Nicole Eikelenberg
organisation: Ford
city: Aachen country: Germany

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

comments (optional): The supervisors have expertiese in distinct areas. The combined knowledge will help me navigate the challenges expected in the project.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

TU Delft

Procedural Checks - IDE Master Graduation

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

Digitally signed by Milene Guerreiro Goncalves - IO Date: 2022.03.23 22:53:45 +01'00'

chair Milene Guerreiro Gonçalves date 23 - 03 - 2022 signature

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: _____ EC

Of which, taking the conditional requirements into account, can be part of the exam programme _____ EC

List of electives obtained before the third semester without approval of the BoE

YES all 1st year master courses passed

NO missing 1st year master courses are:

name date - - signature

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **.
Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: APPROVED NOT APPROVED

Procedure: APPROVED NOT APPROVED

comments

name date - - signature

Initials & Name V Balakrishnan Student number 5317436

Title of Project Design with data: Practicing exploratory inquiring on data visualization

Design with data: Practicing exploratory inquiring on data visualization

project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 10 - 02 - 2022 - - end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

A new generation of smart vehicles enabled by complex interconnectivity opens vast possibilities for innovation in mobility. The connected nature of these products, services, and ecosystems generates an astounding amount of data every second. Research and development in technology and fundamental sciences have made it possible to collect, manage and process data to improve quality and optimize design decisions (data-driven). Although using data in design is not new to the automotive industry, it is restricted predominantly to evaluating and decision-making phases. Ford Motor Company, a leading American automotive manufacturer, has access to abundant data about the user, context, and vehicle with varying levels of detail. They aim to leverage this resource and incorporate data into their design process not only for validation but as a tool for exploration within their smart vehicles concept team. Having done a series of projects with graduate students and university research collaboration, Ford is closer than ever to start using data as creative material to inform and inspire designers in their projects.

Data can be broadly classified based on the quantity of available samples (big and small) and contextual richness (thick and thin). Ford wants to understand how data from these four quadrants (Fig:1A) can be combined to generate meaningful and creative insights to support the creative process. Designers at Ford already use qualitative/thick data in their process to understand user behavior and to ideate concepts (Hao, 2021), and there is a lot to learn from the thin/quantitative data as well. But, owing to the sheer quantity and lack of context they are not directly reachable to human cognition to process, make sense and gain insights. It needs to be supported by contextual knowledge giving form and meaning to numbers. Data visualization is an effective way to bridge this gap (Knaflic, 2015), to explore data sets and generate more meaningful insights (Fekete, 2008). With the addition of quantitative/thin data to the creative process, designers will have access to much more extensive information about the users, their behavior, and their context.

One of the ways designers tend to generate insights from information is by asking critical questions and reflecting on them. The discipline and practice of the art of asking and answering questions - called 'creative inquiry' is found to be useful in generating this outcome efficiently (Buchnanan, 2015). In the graduation project of Déborah Mellado Cruz (2021), the role of visualization and creative inquiry in data-enabled design is examined using empirical studies. While the project resulted in new knowledge on analysis of questions, the actions leading from the analysis are not dealt with in detail. It establishes a strong theoretical understanding but misses the last mile that Ford must travel to benefit from the projects directly. The knowledge acquired from the research needs to be translated into a tangible outcome like a method or a process (Fig:1B) that can be used to improve the way of designing within the Ford team. It is also important to understand the stakeholders involved in the project. I will be in contact with member(s) from the Smart Vehicles Concept team (SVC) of Aachen, Germany who is responsible for developing innovative mobility concepts. They collaborate with a team called Global Data Insights and Analytics (GDIA), for any data-related service request.

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Personal Project Brief - IDE Master Graduation

introduction (continued): space for images

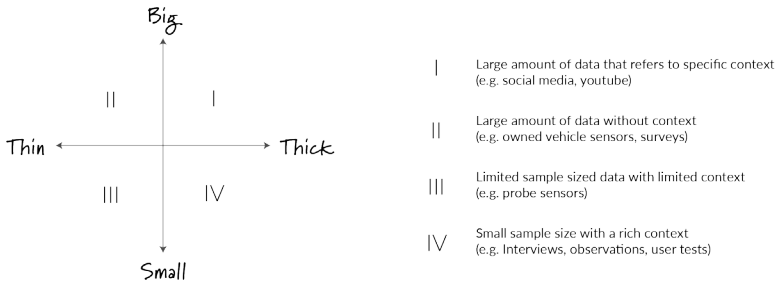

Fig 1A: Data landscape

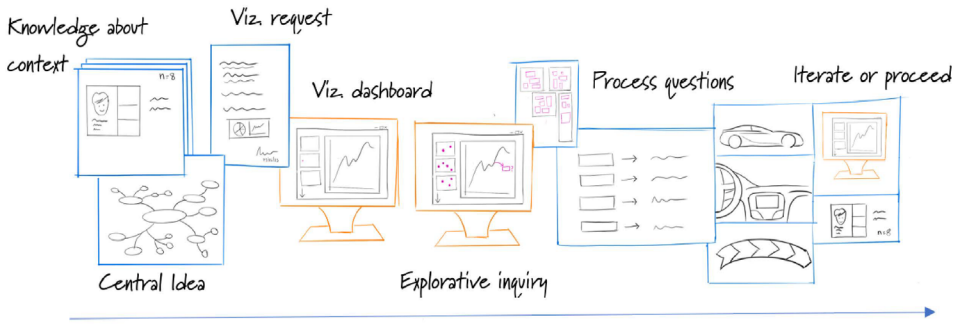

Fig 1B: Initial idea of process flow

image / figure 1:

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image / figure 2: References

Initials & Name V Balakrishnan Student number 5317436

CXX

Title of Project Design with data: Practicing exploratory inquiring on data visualization

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

The line of questions that initiated this project was 'How can quantitative data be used in the exploration phase of the design process?' 'How can designers generate insights from thin data?' 'How can data visualization lead to knowledge creation?', and 'Does the type of data visualization have an effect on the inquiry process?"

There is a good basis to understand that inquiry on data visualization can support data-enabled design, but it is unclear how to apply this in practice. As a follow-up to the project of Cruz (2021), I aim to develop a method to enable the Ford design team to leverage quantitative data in their creative process.

I believe that methods are designed artifacts with an intended purpose to facilitate users to navigate around the process to obtain desired results by making the process accessible, convincing, and usable (Araujo, 2001). With this method, I aim to facilitate design inquiry on data to support designers to extract, process and act upon insights.

Most design methods developed in academia are not directly applied in practice due to of lack of recognition, applicability, and alterability to the specific projects in the real-world (Roedl, 2013). Reflecting on the use of methods in practice as observed by Schønheyder (2018), designers tend to select, adapt, and use several methods together based on project requirements indicating the importance of flexibility for methods to be applicable in practice.

Keeping that in mind, in this project I will explore translating theoretical knowledge on creative inquiry, data viz., and design methods to practical application in Ford design teams. Addressing the gap between design theory and design practice will be an integral part of this project.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

Design the method 'Exploratory inquiring on data visualization' that is fit for use within Ford design teams. Prototype and evaluate the performance of the method when used in different cases based on data and design approach.

The goal of the project is to develop a method to support exploratory inquiring on data visualization in a way that Ford design teams can incorporate in their data-enabled design process. Design methods in practice are seen as a mental tool rather than a step-by-step guide to carry out a process (Daalhuizen, 2014). The outcome of the project would be a design method, comprising of method content (internal logic and contextual positioning), information artifact, (required tools to facilitate the method), along with corresponding mindset to be adopted for different parts of the method (Daalhuizen, 2021).

Creative projects have different starting points based on existing knowledge about the context of interest. Therefore, it is important to understand how the method will fit into different cases based on data availability and stage of the design process.

The expected assignment for the project is series of workshops and interview sessions with designer(s) to understand the method use, to evaluate and to improve the performance of the method iteratively.

Initials & Name V Balakrishnan Student number 5317436

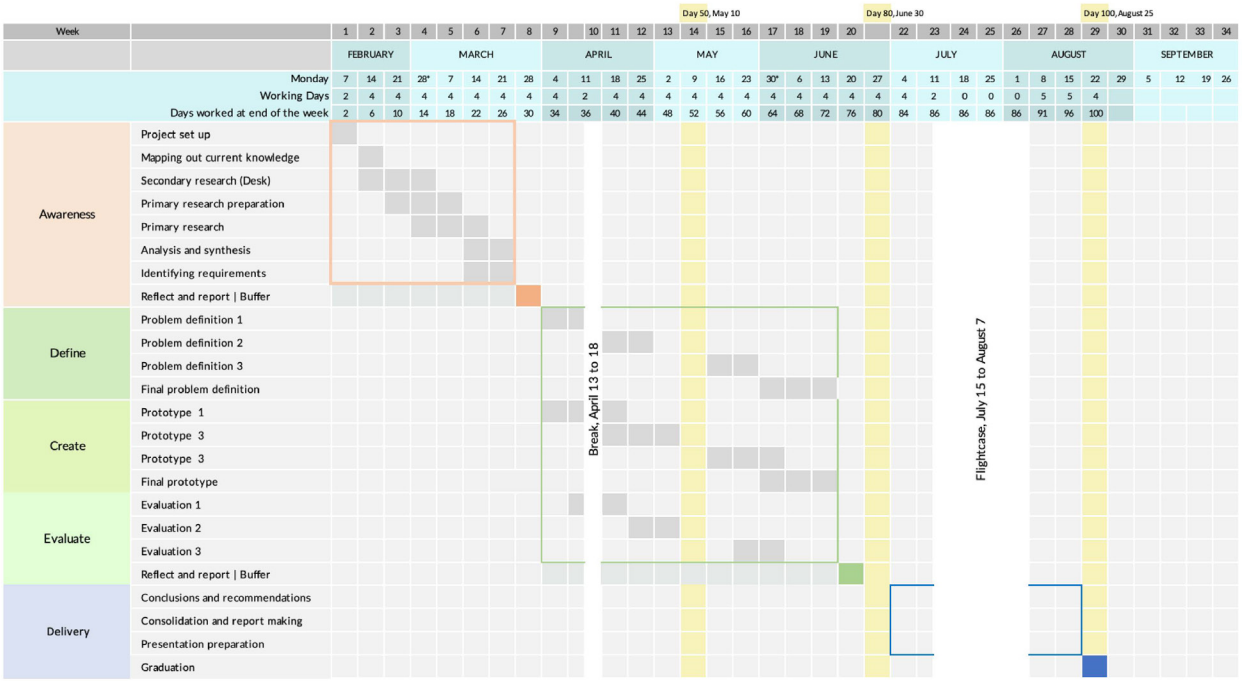
Title of Project Design with data: Practicing exploratory inquiring on data visualization

Personal Project Brief - IDE Master Graduation

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 10 - 2 - 2022 - - end date



The project will have five phases- awareness, define, create, and evaluate followed by time for delivering the project.

Discover: The goal of this phase is to empathize with users to identify potential opportunities. This phase entails collection and analyses of knowledge to understand the problem and challenges in employing thin data for exploratory phase of design process. Literature study will be conducted to strengthen theoretical understanding of concepts like creativity, design theory, data visualization and design inquiry. User research (in the form of interviews) will be performed with the members of the SVC team in this phase to understand the needs and practical challenges involved in integrating the method in their workflow.
Define: Here, the details of the problem will be defined which would drive the structure and function of the solution. It would contain the key design goals which the solution needs to address.
Create: An appropriate solution to the defined problem within the scope of ford design team will be conceived and then realized in the 'Create' phase in the form of a workshop(s).
Evaluate: The proposed process/method will be tested with designer(s) in the 'Evaluate' phase by observations and interview studies. It will improve the definition of problem and solution space for the subsequent iterations.

A total of 3 iterations are planned to prototype, evaluate and refine the method. I intend to test with designers from Ford as part of the final iteration and deliver the refined method at the end of the project. I will be working on the project for 4 days a week and will be guided by the chair and two mentors periodically. Every working week will have a reflection moment and writing report (if applicable) at end of the week.

Initials & Name V Balakrishnan Student number 5317436

Title of Project Design with data: Practicing exploratory inquiring on data visualization

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

During my engineering days, I was always fascinated by data and computation. I was active in solving mathematical puzzles in a competitive computing setting, which help me realize and appreciate the true power of information technology first hand. When I started my design studies, I was curious understand the scope and development in the convergence of data and design. I believe that an integral part of design is synthesis - making sense of the world around the context which requires human intelligence. But, it is fascinating too see how much of this could be supported and improved with the use of technology and data. In the advent of discovering new ways to design, I would like to be in the forefront of this breakthrough in design methodology.

The child-like curiosity in me always motivated me to ask a lot of questions. It was one of these questions that motivated me to pursue this masters as I wanted to learn 'how' to design and commercialize products and services successfully. Reflecting on the courses and extra curricular activities that I pursued during my masters, I realized my interest on the journey or the process undertaken to get a desired outcome or complete an assignment. I was keen on knowing how and why I need to follow certain methods . Self critiquing is one of the important skill that I have trained over my years and it helped me discover my passion towards design methodology. This project is a good opportunity for me to develop competency in research and development of design methods

The master studies 'SPD' trained me develop a critical lens on how to approach and tackle a given problem holistically. I see this project as a special case of design project where i am 'designing' design and the users of are going to be designers. It is fascinating and scary at the same time. Although the studies helped me develop the confidence and tools to identify, conceptualize and solve problems, I feel there is a limitation in implementation and practical aspects. Innovating and implementing within an organization is a daunting task and I would like to take up this challenge enthusiastically and learn more about it.

LO1: Develop competency in design methodology, data-visualization, and data-enabled design.
LO2: Understand and critique use of methods in practice to develop new ways of designing.
LO3: Experiment with iterative prototyping/evaluation cycles to strengthen project outcome.
LO4: Experience innovating and implementing design processes within an organization.
LO5: Explore the possibility of incorporating data across the design process.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

Initials & Name V Balakrishnan Student number 5317436

Title of Project Design with data: Practicing exploratory inquiring on data visualization