VISUAL REPRESENTATION DESIGN FOR COLLABORATIVE COMPLEX COGNITIVE ACTIVITIES

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DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged.

05 September 2016

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ABSTRACT

Visualizations have been use to synthesize information and derive insightful discoveries. Recently, the nature of data have changed and we are now dealing with data that are massive, ambiguous, and dynamic, often processed in real time. As such, they are more complex and the activities that we do with have also become more complex. This research intend to provide for more valuable and effective visualizations. Human centred design is one approach intended to provide an effective solution by understanding the root cause of the needs. By answering the 'why' and 'how' questions on human needs will serve as the foundations for designing user-specific, context-fit, and technology-supported artefacts. However, there are still gaps in the process to understand the root cause and rationalize the design decisions. One issue is with the nature of the activities. In this research our focus is on complex cognitive activities (CCA) which include decision making, problem solving and strategy planning. They all rely heavily on the analytical and synthetical use of information. The challenge increases when there are more than one person doing the analysis. There is lack of understanding of collaborative-CCA and how visualizations can support them and has led to shortcoming of designed visualizations as a tool to facilitate CCA rigorously. It is timely to explore Collaborative-CCA and how to design visualizations based on more human centric approaches. To this end, this research focuses on the most primitive and essential one – design of visual representation. Therefore, the research aims to answer one main question: How to design visualization effectively to facilitate Collaborative-CCA? To achieve the aim, this research is broken down into three research objectives: (i) to identify the challenges involved in collaborative-CCA, (ii) to develop a visual representation design (VRD) theory and principles, and (iii) to evaluate the proposed VRD. Congruent to the necessity to understand the root cause of the problem, the research is based on the Design Science Research Methodology (DSRM) to govern the design process. Furthermore, the qualitative methods of semi-structured interview and focus group observation have been used for conducting evaluations in the real scenarios and settings. This research will have two types of outcomes. The first is an awareness to extend the solution of design complexities from the data in a more effective way in the context of Collaborative-CCA. Three design artefacts have been identified as the research outcomes: (i) a set of challenges, (ii) a visual representation design based on the principle of convergence, and (iii) the evaluation results and guidelines to shed some light during the visualization development. Second, this research will contribute towards the understanding of design process for specific use visualizations.

ABSTRAK

Visualisasi telah digunakan bagi mensintesis maklumat dan menjejaki wawasan dalam penemuannya. Kebelakangan ini, keperluan terhadap maklumat yang dinamik dan dalam pemprosesan masa nyata mendorong kepada lambakan data yang kabur dan pelbagai sumber. Kekompleksan ini turut mendorong sebarang aktiviti yang berkaitan dengannya menjadi lebih kompleks. Justeru, kajian melihat kepentingan untuk meneliti semula kaedah penyampaian visualisasi supaya penggunaannya lebih bernilai efektif. Untuk itu, reka bentuk berasaskan manusia adalah merupakan salah satu pendekatan yang menitikberatkan keefektifan melalui pemahaman terhadap punca sebenar masalah yang timbul. Jawapan terhadap persoalan kenapa dan bagaimana timbulnya permasalahan menjadi asas kepada reka bentuk visualisasi yang lebih spesifik-pengguna, sesuai dengan konteks keperluan dan sokongan teknologi. Namun, masih terdapat jurang dalam proses untuk memahami punca sebenar masalah sebagai rasional dalam sesuatu keputusan reka bentuk. Salah satu isu yang perlu diambil kira ialah keadaan aktiviti itu sendiri. Dengan menjurus kepada Aktiviti Kognitif Kompleks (CCA) yang meliputi pembuatan keputusan, penyelesaian masalah dan perancangan strategi, kajian mendapati CCA adalah mencabar kerana banyak bergantung pada penganalisaan dan pensintesisan maklumat. Penganalisaan dan pensintesisan yang perlu dijalankan oleh lebih daripada seorang pengguna pula mengundang kepada peningkatan cabaran. Lantaran kurangnya pemahaman tentang cabaran Kolaborasi-CCA menjadi punca kepada keterbatasan reka bentuk visualisasi dalam menangani CCA secara lebih komprehensif. Justeru itu, kajian ini melihat kepentingan untuk menerokai fenomena Kolaborasi-CCA bagi memahami kaedah reka bentuk visualisasi yang relevan dengan keperluan manusia dan aktiviti yang dijalankannya. Memandangkan bidang visualisasi adalah luas untuk diterokai, kajian ini fokus kepada perspektif yang paling penting dan primitif - rekabentuk perwakilan visual. Untuk itu, matlamat kajian ini adalah untuk menjawab persoalan: Bagaimanakah reka bentuk perwakilan visual yang efektif untuk menyokong Kolaborasi-CCA? Bagi mencapai matlamat tersebut, kajian dipecahkan kepada tiga objektif utama iaitu: (i) mengenalpasti cabaran bagi Kolaborasi-CCA, (ii) membangunkan rekabentuk perwakilan visual dan (iii) menguji keefektifan reka bentuk perwakilan visual yang dibangunkan. Sejajar dengan kepentingannya untuk memahami punca sebenar permasalahan maka Metodologi Penyelidikan Sains Rekabentuk (DSRM) adalah relevan sebagai panduan dan tulang belakang kajian. Lanjutan itu juga, pendekatan kualitatif menerusi kaedah temubual semi struktur dan pemerhatian dalam kumpulan fokus telah diaplikasikan bagi pengujian dalam persekitaran dan senario sebenar. Kajian ini mempunyai dua dapatan utama. Yang pertama ialah memberi kesedaran tentang keperluan untuk mengembangkan fasilitasi rekabentuk bagi kekompleksan maklumat secara lebih efektif dalam konteks Kolaborasi-CCA. Untuk itu, tiga artifak rekabentuk yang dikenal pasti sebagai hasil daripada kajian iaitu: (i) cabaran-cabaran bagi Kolaborasi-CCA, (ii) rekabentuk perwakilan visual berasaskan penumpuan dan (iii) keputusan dan garis panduan pengujian adalah mampu untuk memberi gambaran, penjelasan dan pemahaman tentang keadaan tersebut. Dapatan yang kedua ialah kajian ini dapat menyumbang kepada pemahaman terhadap proses rekabentuk bagi spesifik penggunaan visualisasi.

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LIST OF ABBREVIATIONS

Abbreviation		
ACD	Activity Centric Design	36
CCA	Complex Cognitive Activities	2
Collaborative-CCA	Collaborative Complex Cognitive Activities	4
Converge-VRD	Convergence of Visual Representation Design	72
DA	Design Artifacts	8
DA1	Design Artifact 1	221
DA2	Design Artifact 2	221
DA3	Design Artifact 3	221
DQA	Deductive Qualitative Analysis	64
DSRM	Design Science Research Methodology	7
G1P1	Group 1 Participant Identification 1	182
HCD	Human Centric Design	34
HCI	Human Computer Interaction	29
HHI	Human-Human Interaction	42
IS	Information Science	7
IV	Information Visualization	7
KV	Knowledge Visualization	2
KVF	Knowledge Visualization Framework	67
LR	Literature Review	8
MBTI	Myer-Briggs Testing Indicator	67
NCA	Negative Case Analysis	117
PID	Participant Identification	60
RO	Research Objective	7
RO1	Research Objective 1	7
RO2	Research Objective 2	7
RO3	Research Objective 3	7
VRD	Visual Representation Design	56

CHAPTER I

INTRODUCTION

1.1 INTRODUCTION

The use of visualizations has been expanding rapidly, and as the amount and complexity of data keeps growing, so is the sophistication and complexity of their corresponding visual representations. The field of visualisation is interdisciplinary, one that incorporates scientific, technological and cognitive aspects. Visualizations focus on amplifying human cognition to promote efficiency in well-defined tasks (Shneiderman, 1996; Amar & Stasko, 2004; Hundhausen, 2013). More recently, they have been used as a communication mediator to build common understanding, insight, and decision-making within organization environments (Burkhard & Eppler, 2004; Bresciani & Eppler, 2010; Bertschi et al. 2011). After more than 30 years of advancement, visualizations have become very important, almost indispensable, and are used in many application domains (Masud et al. 2010; Meyer, 2009). The domain and context that visualization need to facilitate are becoming more complex, while general design guidelines for developing visualization remain necessary to make good design decision, by themselves they are not sufficient to guide the design for specific use visualization since it does not address how visualizations can be applied as an extension to the user's cognitive ability nor its own context. (Ziemkiewicz et al, 2012).

Today, organizations are the prime domain of visualization. By using interchangeably terms, the visualization has been widely used to facilitate the cognitive process in an organization. From basic presentations aids like Power Points, Prezi and Keynote to more sophisticated tools like Decision Support System,

Knowledge Management, Business Intelligent and currently Big Data – visualization has been used to facilitate the decision making, analysing, forecasting, strategising and sense making – which is in a larger extent called Complex Cognitive Activities (CCA) (Sedig & Parsons, 2013; Johnson, 2010).

According to Funke (2010), CCA can be regarded as hierarchical and emergent in nature. The context of the CCA process emerge from lower-level tasks, which emerge from lower-level actions, which emerge from lower-level events. In addition, each level may be classified at finer levels of granularity: a complex cognitive activity may include sub-activities, a task may include sub-tasks, and so on. In addition, CCA is different from simple cognitive because it involve higher level cognitive activities and various level granularity of sub-activities, tasks, actions and events. Furthermore, the element of complex in this kind of cognitive activities is different from complicated and simple condition. Eventhough complicated and complex ensemble of many parts, complex condition is context dependent and the outcomes in always uncertain and unpredictable. So it has the elements of emergent and evolution. Therefore, the interchangeably solution for complex and complicated visualization is clearly a mismatch. We must provide the visualization solution according to CCA condition

In order to provide the rightful visualization solution according to CCA condition, the visualization field must be able understand and facilitate the CCA process instead of CCA agents or elements. However, due to the increasing level of information load and its complexities, as ilustrated in Figure 1.1 has drive more significant challenge in handling CCA. As a consequences, human and organization are having difficulties and unable to cope with CCA in this kind of the situation (Kearney, 2010). Generally, visualization field is also evolving according to the increasing of information overloaded and its complexities. In 1980s the CCA need to handle field of visualization and its roles has been evolve accordingly. By referring to Zhang et al. (2010), they stated the process of development of visualization started from scientific computer visualization from displaying the visual form in 1980s and within the last of two decades, IV has been developed as an alternatives to handle overloaded information by transforming digital information from textual into visual

form and recently, knowledge visualization emerges with more emphasis on knowledge communication, creation and reasoning (Bertschi et al, 2011; Chen & Floridi, 2013).

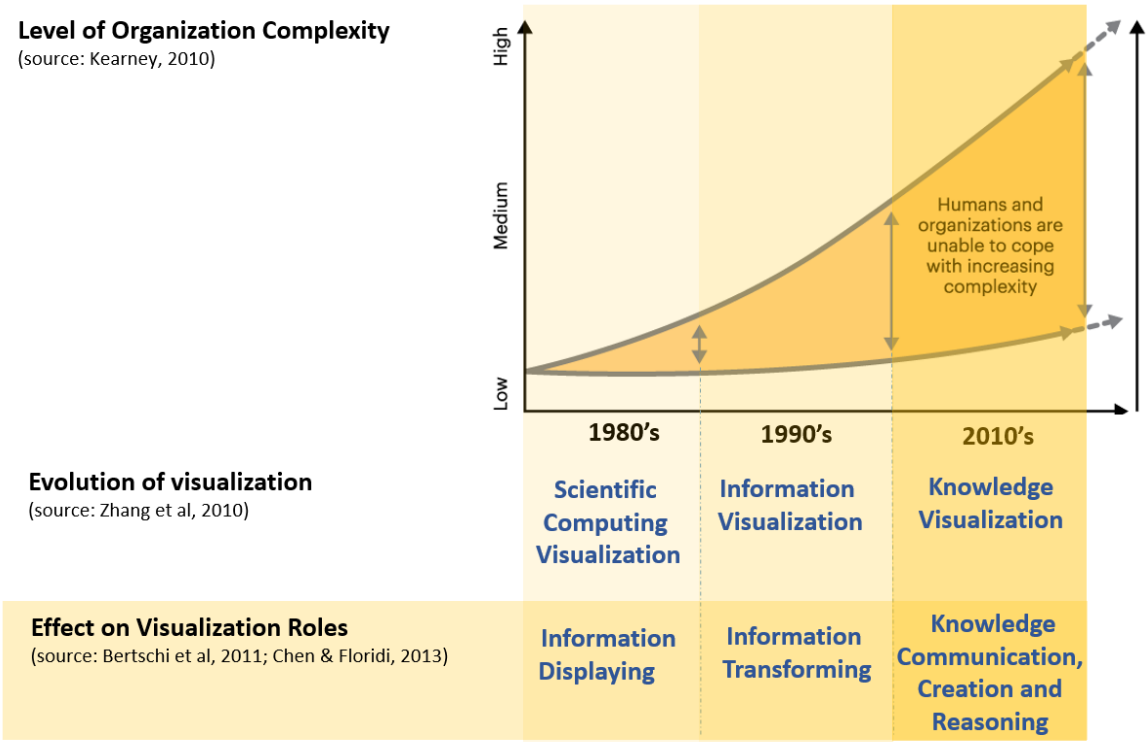


Figure 1.1 Effect of the Organization Complexity for the visualization field and its roles.

Therefore, the current visualization research has been aware about this condition and start an initiatives to develop visualization design that able to enhance communication and foster knowledge for CCA based on their activity and process in the organization. However, their design basically for general or individual use. Whereas in the organization, the norm for CCA happen in the collaborative settings. To arrive at any decision, the CCA process requires the views from multiple participants (usually experts from different areas within the enterprise, in different expertise, and are familiar with their own ways of data representation and analysis, which are known as a collaboration. Collaboration is an essential for productivity and innovation in organizations. Collaboration implies a team to perform a task jointly, thus requiring interactions and coordinations of cognitive effort. Collaborative activities often require high level of cognition (Kolfschoten & Brazier, 2012). Moreover, as an organizational management system is increasingly complex and

dynamic, the collaboration between the higher level executives and top management have to deal with increasing of complexities and different mental model challenges during the CCA.

As collaboration is essential, the activity and process in the CCA also change accordingly. More challenges need to be handle in order to develop suitable visualizations to facilitate CCA in the collaborative settings. Hence, the development of suitable collaborative visualizations is now one of grand challenges in the area. According to Isenberg et al. (2011) citing Raje et al. (1998), a collaborative visualization "enhances the traditional visualization by bringing together many experts so that each can contribute toward the common goal of the understanding of the object, phenomenon, or data under investigation". Further than that, providing an effective visualization to facilitate the collaborative CCA process is significant for an organization to get valuable innovations and outcomes (Hoque & Baer, 2014).

1.2 PROBLEM STATEMENT

There is much to be understood about the nature of representing CCA with visualization, especially from the collaborative sense (Isenberg et al. 2011; Bresciani et al. 2008; Bresciani & Eppler, 2011). In these kind of collaborative situations, a visualization for CCA is not only dealing with heterogeneous, multi-type, multi-faceted and time sensitive data (Thomas & Cook, 2005), but it is also essential to address the need to support cognitive processes and communicate analytical results that meet all the participant's neccessities.

While there is an effort from visualization perspectives to support CCA. For instance, Sedig & Parsons (2013) provide an epistemic framework for CCA visualization interactions, Ziemkiewicz & Kosara (2010) emphasize the importance of dynamic higher level structure and Liu & Stasko (2010) suggest distributed cognition as visual model reasoning. While these are an important contribution, this is only a beginning, given for example that their studies has not considered collaborative perspectives. Therefore, it is a significant needs for visualization to handle collaborative setting during CCA (from hereafter, we simplify the term as

‘Collaborative-CCA). Although there has been some realisation of the need to cater the visualization for collaboration, hence, we observe it is still in its early stage and there is much to be understood about how visual representation should be designed to support collaborative activities (Isenberg et al. 2011) as illustrated in Figure 1.2

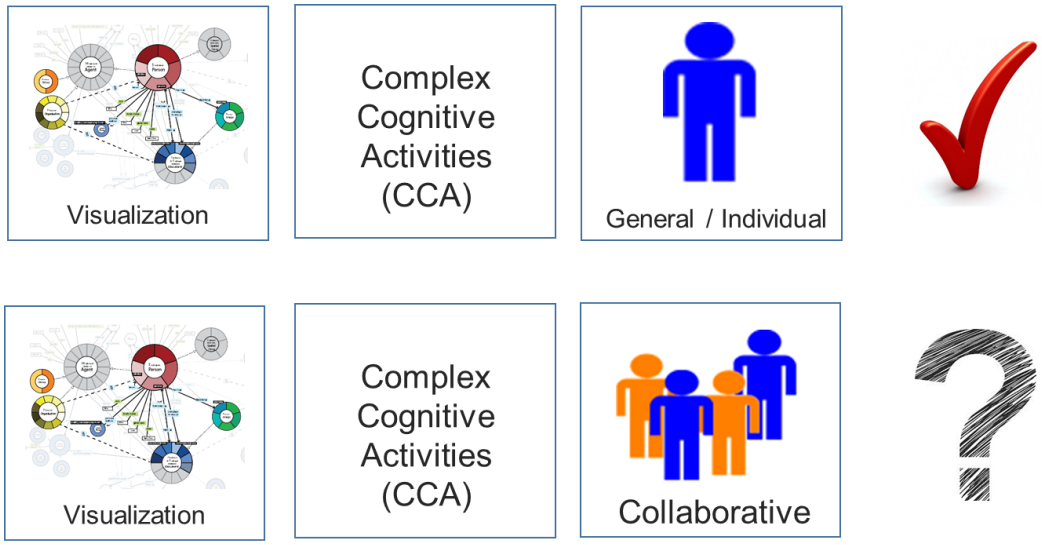


Figure 1.2 The needs for visualization to support CCA in the Collaboration Settings

Furthermore, from an early observation for Collaborative-CCA scenario, issues and approach in the real management and organization settings, they faced the difficulties and aware of the needs for help during the collaborative-CCA process, especially when involved in the higher level meetings and discussion. During these periods, it is difficult to grab, understand and derive for the rightful decision, the CCA misunderstanding during the collaboration will result ineffective solution and it is possible that the giving solution might create a new problem and be somewhat misleading. Therefore, we believe it is timely that we must revisit the way in providing an effective visualization for specific use, in this case is Collaborative-CCA phenomenon in the organization domain. By exploring the situation and approaches further, the research believes it can provide more valuable and effective visualization for the Collaborative-CCA.

1.3 SCOPE FOR THE RESEARCH

Since the specific use visualization for Collaborative-CCA is still new in the research and in view of the fact that visualization is the massive field to contribute, the thesis focuses on the most primitive and essential of creation – design of visual representation. The visualization basically has four dimensions; representation, content, interaction and organization (Adnan et al. 2008) and Fast & Sedig (2010) classified into three perspectives: content, representation (include organization) and interaction, thus the research limit the design for the most primary perspective – visual representation.

By focusing on visual representation design perspectives, this research intended to further understand the Collaborative-CCA phenomenon in order to develop design solution for it. Therefore, this research further scope the Collaborative-CCA visual representation design by focusing on:

- The management in the organization domain and its Collaborative-CCA related application.

- Activity based that has an open ended goal, context dependent and sequential process (e.g Decision making, problem solving and strategy planning)

- During Collaborative-CCA Process by limiting on face to face collaboration that happen at the same time of synchronous and same space of co-located (e.g, meeting, classroom or forum).

- Multiple participants as the collaborators in the CCA process (regularly are among expers and decision makers).

The research aim, questions and objectives for this thesis will be based on these scope.

1.4 RESEARCH AIM, QUESTIONS AND OBJECTIVES

After understand that visual representation can be manipulate to enhance cognitive in its specific context, in this case it should be able to facilitate and coordinate the CCA in the collaboration settings. Thus, the design of visual representation must be according to that specific context and these design is what the research intend to explore and answer.

Therefore, this research is exploratory. It aims to answer one main question: How to design visualization effectively to facilitate collaborative settings in complex cognitive activities (Collaborative-CCA)? Hence, the research aim to design visual representation as an effective solution in order to facilitate Collaborative-CCA in the organization. Regarding on the research aim, the purpose of this thesis is to come out with an effective visualization design for facilitating collaborative settings in complex cognitive activities. This aim is comprised of three research objectives:

- Research Objective 1 (RO1):
  To identify the Collaborative-CCA Process Challenges

- Research Objective 2 (RO2):
  To develop the visual representation design as the solution to handle the Collaborative-CCA Process.

- Research Objective 3 (RO3):
  To evaluate the proposed design solution.

1.5 RESEARCH METHODOLOGY

The Design Science Research Methodology (DSRM) has been choosen as an overall strategy to govern this research. DSRM is capable of integrating different component of the research in a coherent and logical way of design. DSRM has been accepted and well-known in Information Science (IS) discipline (Hevner, 2004; Vaishnavi & Kuechler, 2007; Peffers, et al. 2006) as the larger extent of the Information

Visualization (IV) field. In general, DSRM is similar to the 'problem solving' concept. It explores the problem and then creates new solution in the form of design artifacts (DA) in order to handle the problem in more comprehensive and rigorous way (Hevner, 2007). This research applies Peffers et al (2006) phases and examplery from Geerts (2011) to develop the visualization design by following six nominal activities as listed:

- Identify the problem and motivation
- Identify the object of solution and theorising
- Explicate the design solution
- Demonstrate the use of the solution in the real environment
- Evaluate the solution based on research objectives
- Communicate the research problem and its solution to the relevant audience

We found DSRM is suitable to govern this research because it is congruent with the research aim of creating a new design solution and complementing human-activity centric design. Using DSRM, we align the research objectives according to the DSRM phases. Even though the research design proposed each of the phases based on their own goal and derive its own outcome, the outcomes are interconnected to support and approve the visualization design as the main outcome. By using DSRM, the research expects to identify the Collaborative-CCA problem, develop the visual representation design as the solution and then evaluate the effectiveness of the solution in its natural settings. Moreover, the demonstration of Collaborative-CCA will lead to the knowledge on how to design specific use visualization as a contribution from the overall research. Other than that, since DSRM appreciates theories and practicalities, the research has relied enormously on Literature Review (LR) and qualitative method as well. Basically, the research design applies qualitative approach to observe the nature of human-activity centric in order to apply, verify, enrich and expand the design theories in hand. This methodology will be further explained in Chapter 3.

1.6 THESIS OVERVIEW

In achieving the research aim and objectives, the remains of the thesis is structured as depicted in Figure 1.3 and explained in the following paragraphs:

Chapter 2 reviews the literature about the current situation of Collaborative-CCA that has been handled from visualization perspectives. Since the LR plays an important role and will be enormously used in the overall research, thus chapter 2 will focus only on the current state of the art of visualization field towards the Collaborative-CCA context and the gaps to fill in. The research intends to have some clarity about this situation using 5W and 1H techniques. Basically the first 4W ('What', 'Where', 'When' and 'Who') will clarify and inform the situation, 'Why' to understand the underlying assumption for the cause of situation and 'How' to handle the situation. By having the clear picture and good understanding about each and the interrelation between these six elements, the research expects to gain real understanding about the visualization in handling specific use of Collaborative-CCA. Furthermore, the view for its current conditions, strengths and shortcomings will provide more directive and clearer research path.

Chapter 3 describes the research methodology that governs this research. Since the nature of this research is similar to the 'problem solving' method and its prime focus is about the design, we explain the significance of having DSRM as the research backbone. The thesis emphasizes an epistemological point of view by understanding the research philosophy, mode and directions in order to explain the research context, clarify the research direction and further justify the selection of DSRM to underpin the research design. Futhermore, the thesis will also explain the consideration for qualitative approach and describe an overview of DSRM – its frameworks, cycle, outcomes and phases. As the core for this chapter, the research design will be thoroughly explain by aligning the DSRM phases with the research objectives. The thesis is having three main activities and each will be described according to the research design based on its own objectives. Thus, the process, methods, data management and analysis and its expected outcomes will be discussed appropriately.

Chapter 4 aims to identify the Collaborative-CCA challenges. For specific use visualization, identifying the root cause challenge based on its context is essential as a rationale for visualization design. Thus, this research dedicates chapter 4 to develop an understanding about Collaborative-CCA as its context and expects a set of challenges will be identified as an outcomes. Within this chapter, the research develops an understanding about the intersection of CCA and Collaboration challenges. Through the LR point of view, the research intends to develop a strong foundation of the challenges. Then, using semi-structured interview, the research verifies and expands on how each of the challenges has been taken in the real environment. Finally, these challenges will be amend congruently.

Chapter 5 is to develop the prime artifact for this research - the visual representation design solution as a Collaborative-CCA facilitation solution. Basically the design solution contains the design theory and principles in order to handle the identified challenges. Mainly, the design development rely on the description of the theories and prescribe the theorizing. After reflect the challenges and define the visualization roles, the thesis will describe the potential theories to govern the challenges and support the visual representation roles, then this chapter will prescribe the design theories and principles by applying the theories to handle Collaborative-CCA context from visual representation design perspectives. Each of the visual representation design principles will be describe in details.

Chapter 6 is about demonstrating and evaluating the visualization solution. To justify the effectiveness of the visualization design solution, the design solution should be able to handle the challenges as identified in chapter 4. Thus, the evaluation criteria derive from the design solution's role that reflect the Collaborative-CCA challenges. This chapter holds two important phases: the demontration on design solution usefulness and evaluation of the design solution to handle the Collaborative-CCA process.

Chapter 7 is intends to discuss the contributions and shortcomings of the research. Moreover, it enlightens some limitations during the research and challenges to be taken for

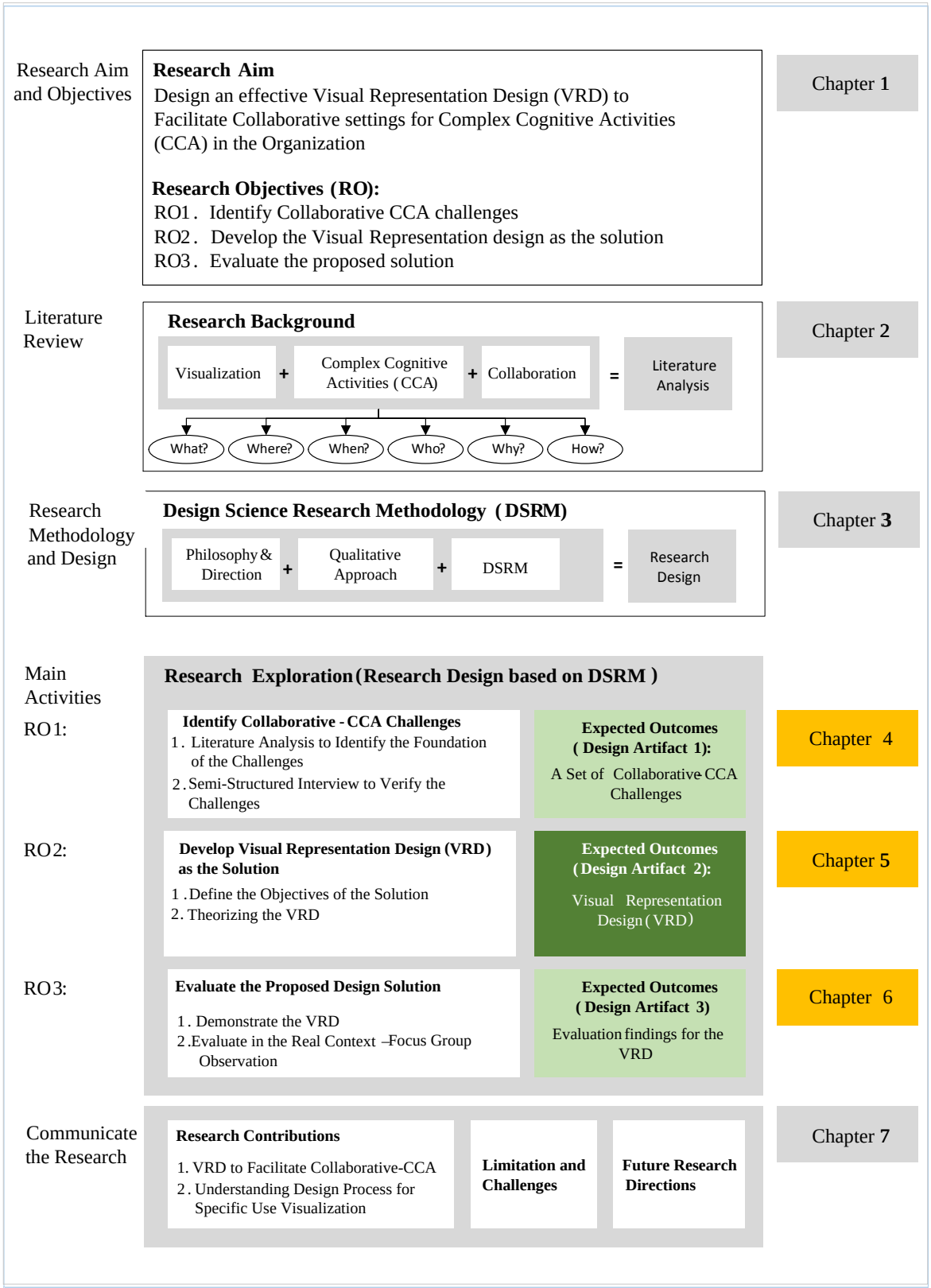


Figure 1.3 The Summary of Thesis Overview

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

As early as civilizations of Babylon and Egypt, visualization has become a medium for conveying information. Although it was abandoned more than 5000 years, the visualization in the form of hieroglyphics is able to convey the information over the period of time, civilization, culture and language that can be interpreted to create new knowledge for today's generation. In the world of computing, visualization continues to be an important element in delivering information. According to Spence (2000), Information Visualization (IV) is one of the branches in Computer Science as an inter-disciplinary fields, one that incorporates scientific, technological, cognitive and aesthetic aspects. It is based on the theory of information design, computer graphics, human computer interaction and cognitive sciences.

Without computer support, the conventional of visualization methods often delegates information for a graph, bar chart or textual interpretation, but all of these methods are limited. Accordingly, more dynamic representations that are able to reflect the real state of events is necessary. Thus, IV focuses on amplifying human cognition to promote efficiency in well-defined tasks. By having a dynamic and interactive components, IV via visual information seeking mantra allows the users to get an overview first, zoom and filter and then get details on demand. According to Schneiderman (1996), the main goal of IV is to reduce the complexity of the examination and understanding of the information. While Amar & Stasko (2004) emphasize the importance of interaction and Ware (2008) has highlighted the visual representation and the organizational structure as a cognitive tools to help the cognitive pattern findings. In short, IV is a computational supported field that transform the information from textual to visual representation and by having computational-supported, interaction component was able to manipulate visual

representation to amplify human cognitive abilities. This is consistent with the definition of IV as follows:

> *"The process of transforming data, information and knowledge into visual making use of humans' natural capabilities".*
>
> (Gershon et al. 1998).

> "*The use of computer-supported, interactive, visual representations of abstract data to amplify cognition".*
>
> (Card & Mackinlay,1999).

After more than 30 years of advancement, in the increasing complexities and massiveness of digital information, IV research has been arises due to the power of visualizations to apply perception and visual thinking in understanding complex, messy, massive and real time of data and nowadays visualizations have been used to synthesize information and derive insightful discoveries (Thomas & Cook, 2005). The paradigm of IV research has shifted from displaying visual form to understanding how and why the visualization works (Huang, 2013). Ziemkiewicz & Kosara (2008) have mentioned that the use of visualization has raised the questions about why IV is able to help human cognitive and how it works by digging and explaining more about the idea of visualization contributes to the reasoning process. The shifting also being highlighted by Zhang et al. (2010), Bertschi et al. (2011) and Chen & Floridi (2013). By referring to Zhang et al. (2010), they stated the process of development of visualization as shown in Figure 2.1. It started from scientific computer visualization from displaying the visual form in 1980s and within the last of two decades, IV has been developed as an alternatives to handle overloaded information and recently, knowledge visualization emerges with more emphasis on understanding perceivedness and human centric visualization.

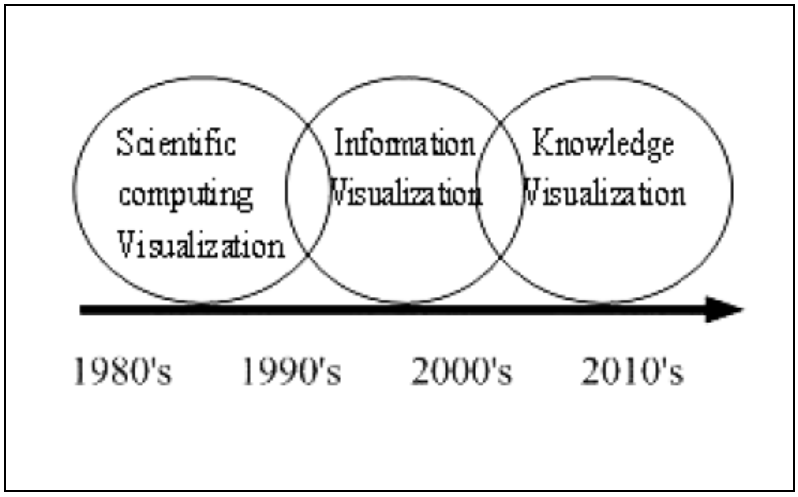


Figure 2.1 The Process Development of Visualization
(source: Zhang et al 2010)

This shifting paradigm also in line with Synthese of IV analysis which recently published (2013) by Chen & Floridi in which has redefine IV as the statement below:

> *"Visualization is a form of 'computer-aided seeing' information in data. As a technical term, 'visualising' refers to different aspects of a visualisation process, primarily in two semantic contexts. Viewing concerns the process of specifying significant or noteworthy information, creating appropriate visual representations, and conveying visual representations to viewers. In the literature on computer visualisation, this is explained intuitively in terms of making visible to one's eyes. Seeing concerns viewers' thought processes and cognitive experiences of interpreting received information and converting the information to mental representations of what the information intends to convey. In the aforementioned literature, this is explained intuitively in terms of making visible to one's mind"*

Since the visualization has evolved from displaying visual form to conceiving knowledge in the human mind, IV has been an umbrella term which refers to all domains using visual artifact with the end result of each domain is meant to convey knowledge. The users should be able to receive, process and deliver the visualization in a more relevant and effective ways.

2.1.1 Visualization Facilitation for Complex Cognitive Activities (CCA)

Align with visualization advancement, we can see the trend of visualization use has been expanding rapidly. The development of visualization is moving towards specific and special application in various domain. As the consequences, the visualization tools, methods and techniques rapidly developed to fill in the current needs and the needs to understand how the reasoning works on visualization is becoming more essential. The process of making visualization visible to one's eye shall be consistent to the process of making visualization visible to one's mind (Chen & Floridi, 2013). According to Zins (2006), the realization from objective knowledge (the application in visualization domain, e.g. specific IV techniques, tools or methods) becomes real and meaningful only to the user who is aware of his subjective knowledge (the context of the IV usage. As an example IV use for specific roles, different level of knowledge and cognitive process). So far, we can see the visualization paradigm shift towards creating an effective, rightful and valuable solution for the people is parallel to the increasing complexities and massiveness of information (Huang, 2013; Albers, 2015). It is clearly that understanding the human perceivedness and its context of use are essential for current visualization needs. Because through an understanding, it can help to answer 'why' questions and rationalize the relevancy of visualization creation. Hence, it helped to develop an understanding on how visualization shall work to generate a more useful, relevant and comprehensive solution.

Today, organizations are the prime applicants of visualization. By using interchangeable terms, the visualization has been widely used to facilitate the cognitive process in an organization. From basic presentations aids like Power Points, Prezi and Keynote to more sophisticated tools like Decision Support System, Knowledge Management, Business Intelligent and currently Big Data – visualization has been used to facilitate decision making, analysing, forecasting, strategising and sense making – which is in a larger extent called Complex Cognitive Activities (CCA) (Sedig, 2013; Johnson, 2010). CCA often involves a higher level of thinking and knowledge. The process of problem solving, decision making and sense making tend to answer the questions of 'how' and 'why' (higher level knowledge). The questions

of how and why require an understanding of the lower level of knowledge (remembering, understanding and knowing) before a user can make an analysis and a synthesis in response to higher levels of knowledge (Krathwohl, 2002) in which the visualization need to support the reasoning in this kind of cognitive process (Gao & Low, 2013; Vlk, 2009; Vitiello & Kalawsky, 2012).

There is much to be understood about the nature in supporting CCA with representations, both at the individual level and in the collaborative sense (Eppler et al. 2013; Bresciani, 2009). Sedig & Parsons (2013) have presented a characterization of interactions for complex cognitive activities with visual representations based on high levels of patterns of these activities. While this is an important contribution, this is only a beginning, given for example that their framework has not considered collaborative settings (Bashir et al. 2014; Sakamoto et al. 2014). Since the CCA in the organization always takes place in the organization settings (e.g: meetings, discussion, experts and decision makers knowledge integration), there is much to be understood about how CCA should be facilitated to support the collaborative activities (Isenberg et al. 2011) which we term as Collaborative-CCA.

However most of the visualization tools are based on the same reductionism and determination approach. Based on the reductionism conception, the visual representation is usually breaking a phenomenon down into its constituent parts. The capacity of the visualization tools supports only a particular part of the whole phenomenon. It restricts a group of users to observe and make sense from many perspectives. The management teams' inadequacy of holism view to facilitate them during the process of CCA. Furthermore, it limits the needs in a complex situation to see the interconnection between each part as the big picture of the whole system. Without a complete perspective, the organization has dificulties to move forward with clarity. They need a more comprehensive view that takes into account the whole system of causes and effects that have an impact on the problem. Hence, visual representation must go beyond the constituent parts and capable to act as epistemic, centralized and explicit guidelines between different mental models and departmental information.

2.1.2 An Effective Visualization Design for Collaborative-CCA

Since the researched aim to develop a further understanding about visualization facilitation for the Collaborative-CCA phenomenon, the research focused on the primitive and essential process of visualization facilitation – design. When discussing about design in the visualization field (generally IV), Moere & Purchase (2011) emphasize the importance of design as 'the conception and realization of new things' which has 'its own distinct things to know, ways of knowing them, and ways of finding out about them' and describe a designer as someone 'who devises courses of action aimed at changing existing situations into preferred ones'. Consequently, designing is 'a pattern of behaviour employed in inventing things of value which do not yet exist'. It consists of various goal-oriented, constrained, decision making, exploration and learning activities, which all operate within a given context, and which depend on the designer's perception of that context.

Design is a process of invention. While science investigates, describes and justifies the problem, design means to create the solution for the problem. Good design occurs at the intersection of constraint, contingency and possibility. Theses elements are needed to create an innovative, elegant and functional design. It has a lot of different meanings that provide the definition of design lies at the core of the argument. Thus, according to the design we intend to explore, the below definitions are appropriate according to the research intention:

> *"Design is a systematic approach to problem solving. It starts with the problem and the ability to create a solution for it. Establishing a deep understanding about the problem and its context lets us discover the real problem and the rationales needs and wants (Liedtka & Ogilvie, 2011)"*

> *"Design as a search activity that aims to find the best solution to important unsolved problems. (Hevner et al. 2004)"*

> *"Design as creating new things, solving problems and moving to desired situations from less preferred situations. (Goldkuhl, 2004)"*

From the above definition, the visualization design for Collaborative-CCA means the creation for a new or a better solution to facilitate the specific Collaborative-CCA context. Therefore, the research intended to develop an effective solution by emphasizing the usefulness of visualization design to handle the Collaborative-CCA context. Basically this research is in line with Covey (1989) that defines effective as *"do the right things instead of do the things rightly"*. Furthermore, DSRM perspective terms an effectiveness as utility – the state of being useful, functional and beneficial to handle any involving situation (Hevner et al. 2004). In order to develop an effective solution, it is important to understand the current concept and condition of visualization design in handling collaborative-CCA. We will use the technique of 5W and 1H (Norman, 2013; Gao & Low, 2013, Murata & Katayama, 2010) to further understand the context of Collaborative-CCA from visualization design perspectives. From these understandings, the research will have some clarity about the current situation and how to move on. Basically the first 4W ('What', 'Where', 'When' and 'Who') will clarify and inform the situation, 'Why' to understand the underlying assumption for the cause of situation and 'How' to handle the situation. This chapter is presented according to this following structure.

2.2. Background of Complex Cognitive Activities (CCA) [What]
2.3. Regular occurrence of Collaboration settings for CCA in the Organization [Where]
2.4. During Collaborative-CCA process [When]
2.5. The Collaborative-CCA Users and their activities [Who]
2.6. The Challenges for Collaborative-CCA [Why]
2.7. Visualization Design Process for Collaborative-CCA [How]
2.8. Literature Analysis and Research Direction
2.9. Conclusion.

2.2 BACKGROUND OF COMPLEX COGNITIVE ACTIVITIES [WHAT]

Complex Cognitive Activities-CCA (e.g decision making, problem solving and strategy planning) is a prime applicant in the organization while dealing with information complexities. There are numerous of computer-supported visualization

studies that have been pursued to facilitate it (e.g Decision Support System, Business Intelligent Dashboard and Big Data). To further understand the CCA, there are three important component within CCA: i) Cognitive Concept, ii) Complex Concept and iii) Complex Cognitive Activities. Each will be further described in the following section.

2.2.1 Cognitive Concept

Generally, Cognitive is involving conscious mental activities such as thinking, understanding and remembering. According to Oxford Dictionaries (2016), cognitive is defined as relating to, being, or involving conscious intellectual activity (as thinking, reasoning, or remembering) and is based on or capable of being reduced to empirical factual knowledge. Cognitive is able to encompass a mental process that includes knowledge, attention, memory, producing and understanding language, learning, reasoning, evaluating, judging, problem solving and decision making. Cognitive is closely related to abstracts concepts such as the mind and intelligence. It encompasses mental functions, mental process (thoughts) and states of intelligent entities (human, collaborative groups, human organizations, artificial intelligence). Hence, human cognitive can happen in conscious or unconscious, concrete or abstract, intuitive (knowledge of a language) and conceptual (model of a language).

From cognitive science and computer supported perspectives, cognitive is always referring to an information processing model in which is the view of an individual's psychological functions (Miller, 2002). As a faculty of information processing, the cognitive applies knowledge and changes the preferences before these processes are analysed from different perspectives within different contexts. In the information processing theory, they take human as computer as a means for a better understanding of the way information is processed and stored in the human mind. Therefore, the storing, analyzing and encoding memories are the main concerns in the information processing theory.

Further than that, cognition is the process of mental action to acquire new knowledge and understanding through experience, thought and senses. The cognition or cognitive process is the performance of some composite cognitive activity, such as

an operation that affects mental contents and the process of thinking and remembering. Generally, basic cognition involves the process in obtaining, storing and encoding the information. In contrast, the higher cognitive process is involved in more than storing and encoding memories as it must come with the ability to presuppose the availability of knowledge and put it to use. For the higher cognitive process, Woolfolk (2005) term it as 'Complex Cognitive Process' in which it recognised those processes that lead to understanding and the ability to transform and use knowledge in the appropriate context settings. The conception, thinking skills, problem solving and decision making are among the components of the complex cognitive process.

From the perspective of computer-supported visualization, Complex Cognitive Process is the interaction between various parts of tasks, actions and events for solving a higher level of cognitive activities (Sedig et al. 2014). It is also supported by Bodenschatz (2009) to which he mentions that the complex system may have many components (elements or spatio-temporal fields) that collaborate to create a functioning whole. In the complex cognitive case, the function creates itself by the dynamical interaction of the lower component without an intervening regulatory body. Mitchell & Newman (2002) emphasized the importance of the interaction between the individual parts in the complex system that lead to large-scale behaviours which are not easily predicted from knowledge only of the behavior of the individual components. Impact of the collective effects of the interaction will lead to the human to solve their cognitive activities.

2.2.2 Complex Concept

Most of the visualization applications concentrate to deal with information complexities. One of the problems in discussing this situation is that we do not yet have a clear way to describe information complexities. Even though Thomas & Cook (2005) describe it as "massive, messy, diverse and ever changing volumes of information", we are still unclear about the root cause of the complexity. Generally, complexity is a term used to characterize the system with many parts that interact with each other in multiple ways. Johnson (2010) admits that even among scientists, there

are no unique definition of complexities and the scientific notion has traditionally been conveyed using the examples. However, the complexities can be characterized as below:

- The system contain a collection of many interacting objects or agents.
- The objects can adapt their strategies according to their history.
- These objects' behavior is affected by memory or "feedback".
- The system exhibits emergent phenomena are generally surprising and extreme.
- The emergent phenomena typically arise in the absence of any sort of "invisible hand" or central controller.

Ng (2011a, 2011b) explains the complexities can come from a complex or a complicated situation or a combination of both. However, there is a thin line to differentiate between these two and people tend to use the terms *complex* and *complicated* in the description, often with one being synonymous to the other. According to Glouberman & Zimmerman (2002), systems in the organization can be classified as being simple, complicated, and complex. Simple systems are always straightforward and follow a linear process, such as arranging documentation and filing by following a sequence of instructions. Being the opposite of simple, a complicated system is non-linear, having multiple entities and many moving elements that interact with each other. Their complicated nature is often related not only to the scale of the problem and number of interacting elements but also issues of coordination or specialized expertise. Finally, a complex system also has multiple interacting entities, and their properties of self-organization, interconnectedness and evolution, which make them look complicated. As such, it is sometimes hard to differentiate between complex and complicated.

Even though the differences between complicated and complex can be subtle, yet are important to our discussion in understanding the organization needs while dealing with information complexities. Aside from the fact that complex systems have

a lot more interacting elements, another key differences is based on their outcomes. The outcomes of a complicated system is usually determined, predictable, by things like good algorithms, calculations, specifications, and controlled structures. For instance, we can be certain of the success of designing the structure of a new house if we are following one success coordination and specialized expertise of the previous architectural and design procedures. A complex system, on the other hand, cannot be understood solely by simple or complicated approaches. The outcomes of a complex system are not certain and predictable, but are rather emergent.

This same condition can be transferred to organization. Many business decisions are natural phenomena that are unknown and emergent. For instance, in solving a problem in the organization, the success of solving one problem provide experience but no assurance of success with the next, as each problem can be very different than the other. Every problem is unique and must be understood with constant adaptation in design, action and emergent effect. Therefore, for the organization to effectively deal with information complexities, instead of quarreling about the messy and massive of it, more importantly it is essential to represent the information in a way capable to support business decision that are complex rather than complicated. Hence, we can see the problem in misidentifying complex and complicated issue in the current of visualization approach. By not understanding the root cause of information complexities phenomenon, the research found the effect of mismatched visualization solutions that deviate the organization's real needs to handle complex situations.

a Mismatched Visualization Solutions

Complicated systems can use the most sophisticated math technical and engineering expertise in mapping out the flow charts of the process to solve a problem (Byrne 2014). But from time to time, this sophisticated system fails to solve human resources problem solving, long term strategic planning and decision making which are basically *complex* problems. One of the obvious mismatches is that traditional computer science and engineering training have taught us that when dealing with a system, we need to reduce it into simpler constituents. It is based on the reductionism

theory that holds that a system, complex or not, is the sum of its parts and that an account of it can be reduced to accounts of individual constituents. This approach is appropriate if we want to handle a complicated situation, but it may not be suitable to handle a complex one. This is because in a complex situation, it is much more than a sum of their parts. It is often characterized as having extreme sensitivity to initial conditions as well as having an emergent behavior that is not readily predictable or even completely deterministic—this is giving the evolving nature of the data. Outcomes in a complex system usually emerge from the dynamic interaction of its constituent elements over time. When dealing with data that is "*massive, messy, diverse, and ever changing*" using a complex view to the creation of visualizations can represent a more suitable approach. Misidentifying the correct type of visual support will result in an ineffective solution, and it is possible that the giving visualization solution might create a new problem. We may be trying to use deterministic and complicated tools to handle a complex data set—a clear mismatch.

b Challenges in Complex System.

In investigating for matching visualizaton solutions, the research must first get a further understanding about the complex features that bring challenges as the complex phenomenon. Since the complex systems are systems that comprise many interacting parts with the ability to generate new collective behaviors through self-organization and re-arrangement of these elements, then the complex system is adaptive as they evolve, and may contain self-driving feedback loops. Thus, complex systems are much more than a sum of their parts.

According to Mitchell & Newman (2002), a complex system is a group or organization which is made up of many interacting parts. Archetypal complex systems include the global climate, economies, ant colonies, and immune systems. In such systems the individual parts—called "components" or "agents"— and the interactions between them often lead to large-scale behaviors which are not easily predicted from knowledge only of the behavior of the individual agents. According to Bar-Yam (2002), a complex system is a new field of science studying how parts of a system and their relationship give rise to the collective behaviours of the system, and how the

system interrelates with its environment. This field reflects its potential impact on our ability to understand questions that affect everyday life, perspectives on the world around us, fundamental philosophy disputers and issues of public concern. The LR have provided various characterization that bring challenges in a complex system. Although the existence of these LRs show the varieties of characterizations, there are enough commonalities between the characterizations. Thus, the commonalities enable the research to derive three features that arise challenges in a complex system. Table 2.1 is a features' summary for a complex system by reviewing various attempts of complex system characterization in the literature. Each of the paragraph below will explain about complex system challenges as: i). Ensemble of many elements, ii). Emergence and iii) Evolution.

Table 2.1 Comparison of characterization that arise challenge for Complex System

The LR commonalities	**Ladyman & Lambert (2013)**	**Mitchell & Newman (2002)**	**Bar-Yam (2002)**	**Nordin & Banzhaf (1995)**
Ensemble of many elements	Ensemble of many elements	Interacting parts	Interaction element	Interaction of many parts
Emergence	Interaction means	Collective effect of interation - Emergence	Emergence Interdependence – cause and effect	Emergence – the appearance of qualitatively new phenomena on higher level of a hierarchical system
Evolution	Disorder Robust disorder Memory	Evolutions – sophisticated organism forms that are highly adapted to their particular niches	Evolution from self organizing pattern	Evolution – a process of change in some direction

i Ensemble of Many Elements

A complex system is an ensemble of many elements which are interacting in a disordered way, resulting in robust organization and memory. In the definition or description of complexity, 'many elements' is mentioned as a characteristic. For interaction to happen and for pattern and coherence to develop, the elements have to be not only many but also similar in nature. This is the prerequisite for the condition

of interaction. For systems to be able to interact or communicate with each other they have to be able to exchange energy or matter or information. Physical systems have to be particles comparable in size and weight, subject to the physical laws. In biology, cells before they form multi-cellular organisms are indistinguishable/identical so they can maximally communicate with each other. Non-physical systems, e.g social structures have to be similar in character, behavior or rules obeyed. While it is a necessary condition for a complex system that there are many similar parts of some kind it should be noted that not all of these parts have to be similar and of the same kind.

ii Emergence

Mitchell & Newman (2002) emphasize the key feature of a complex system is the cooperative interactions of the individual components, which determine the emergent functionalities, which individually do not exist. The condition of the system to have the means of interaction can be either an exchange of energy, matter or information. The mediating mechanism can be forces, collision or communication. Without interaction, a system merely forms a soup of particles which necessarily are independent and have no means of forming patterns or establishing order.

Emergence is the idea of the independence of the states of the elements on each other. Non-linearity of interaction is often mentioned as necessary condition for the emergence. It is the creation of a new level organization through the coming into existence of one or more self-sustaining elements or agents. These elements often co-exist in populations of other elements which are more or less similar to one another. According to (Johnson 2010), emergence refers to the ability of low-level components of a system or community to self-organize into a higher-level system of sophistication, since a complex system enables us to explore patterns and relationships between elements and processes rather than only focusing on individual entities or agents. As emergence is the main feature of complex system, we can explore the emergence aspects and the synergy created by their interconnectedness.

iii Evolution

According to Ladyman & Lambert (2013), a system consisting of many similar elements which are interacting in a disordered way has the potential of forming patterns or structures. This means that, although the elements continue to interact in a disordered way, the overall patterns and structures are preserved. A macroscopic level of robust order arises out of microscopic interaction of disorder and it is stable. In which Mitchell and Newman (2002) term this condition as an evolution of sophisticated organism forms that are highly adapted from their particular niches. Then it builds up and need the memory to hold the constructive of evolution process.

Moreover, Bar-yam (1997, 2002) mentions about the patterns that form without someone putting each part in a particular place to make a specific structure that will do a specific structure. That pattern is simply to happen by itself. It self-organises like a process of development. Thus, in understanding the evolution in the domain, the research must understand how this self-organizing process takes place. By then, the research will develop an understanding about the mechanism by which pattern form and how the pattern that arises is determined. Lastly, Bar-yam proposes the idea to specify a process that will create the system that we want to make instead of specifying each of the parts of a system we want to build. This process would use the natural dynamic of the world to help us create what we want to create.

2.2.3 Complex Cognitive Activities (CCA)

According to Parsons & Sedig (2014a), cognitive scientists make a distinction between simple and complex cognitions. Simple cognition refers to elementary cognitive and perceptual process whereas complex cognition refers to high-level, emergent cognitive processes, such as decision making and problem solving, that take place in complex environments and/or under complex conditions. To emphasize the active aspect of such cognitive processes and their complex nature, complex cognition can be referred to as Complex Cognitive Activities (CCA). One of the difficulties in understanding CCA is that it is a high level cognitive activity that involves numerous sub-activities such as problem solving, sense making, analytical reasoning, knowledge

discovery, planning and decision making. Researchers are often not clear about distinguishing between these activies and, as a result, such terms are often used interchangeably and make people more confused. Regarding to Sedig et al. (2012), to clearly discuss various dimensions of complex cognitive processes, the research in the area of visualization science proposes that activities be analyzed at multiple level of granularity. Then Sedig & Parsons, (2013) and Parsons, (2014) identify that CCA can be analyzed at four levels as described in Table 2.2.

Table 2.2 Four Levels of Complex Cognitive Activities

Category	**Description**
Activities	Activities occur at a high level and are often complex and open-ended. e.g. Triaging a set of documents to find out whether they are semantically related may be comprised of lower level tasks
Tasks	Tasks are goal oriented behaviours that occur at a lower level during the performance of activities e.g. Scanning the documents, extracting information, building association among similar information item and comparing these items
Actions	Actions occur at an even lower level and involve actions that are performed upon DIRs and their consequences reactions e.g. Selecting a document, opening it, navigating it, selecting some items in it and copying some items from it * Each of these actions in turn can be implemented in many different ways and using different input techniques, all the way down to low-level events.
Events	Events occur at the lowest level and are the building blocks of interactions. e.g. Mouse click, gestures and touches at the physical level of the interface.

CCA can be regarded as hierarchical and emergent in nature (Funke, 2010). In the context of the CCA process, CCA emerge from lower-level tasks, which emerge from lower-level actions, which emerge from lower-level events. In addition, each level may be classified at finer levels of granularity: a complex cognitive activity may include sub-activities, a task may include sub-tasks, and so on. Each task would likely involve the performance of any number of interactions. For instance, to achieve the activity of triaging a set of documents to find out wheter they are semantically related may be comprised of lowerlevel tasks such as scanning the documents, extracting information, building associations among similar information items, and comparing these items. The task of extracting information may involve such actions as selecting a document, opening it, navigating it, selecting some items in it, and copying some items from it. Each of these actions in turn can be implemented in many different

ways and by using different input techniques, all the way down to a low-level like the example shown in the Table 2.2.

2.3 REGULAR OCCURENCE OF COLLABORATIVE SETTINGS FOR CCA IN THE ORGANIZATION [WHERE]

In providing visualization for CCA, we observe a general trend in organization towards an emerging information from internal (e.g knowledgeable workers, R&D findings, strong financial) and external (e.g trends for users demand and competitors). However, the determination approach in visual representation locks the CCA into a course that disregards any input other than information provided by the application. It cuts off the possibility of improvisation and deviation and the chance to adapt new inputs. Whereas, the management team need to have a more flexible and open ended visual representation to handle their constructive knowledge and allign the emergence of information with their cognitive process goal while performing the complex cognitive activities. Furthermore, while handling the complex situations, today's visualizations need to represent vast amounts of information, with users often requiring to access and combine information from different sources, domain, types, times, and activities. For instance, to support decision making about a new product in the market, analysts may need to access the real time data of customers, demand trends, operational procedures, legal policies and society contributions for the potential decisions to be taken (Aman et al. 2014) and views from experts and skilful people are important for each of the data domain. Thus, it is no longer feasible to tackle the CCA by single people. It needs the collaboration among management teams, and the contributions from decision makers, whereas experts and managers are crucial to handle the increasingly large, complex and various domain of information as illustrated in Figure 2.2.

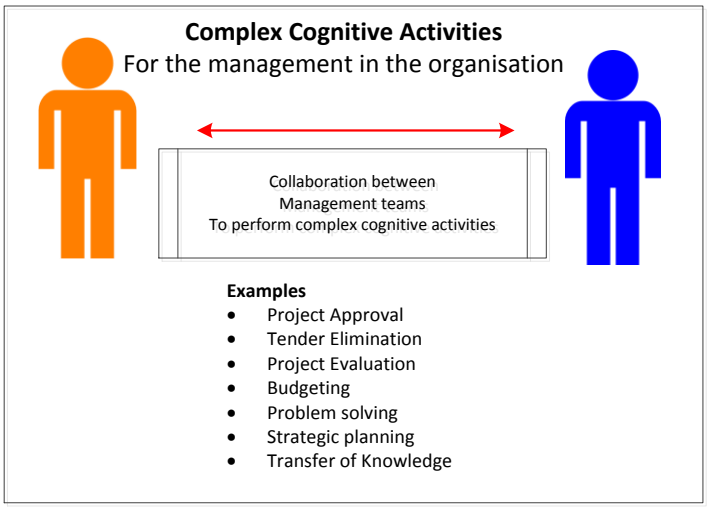


Figure 2.2 Collaborative-CCA in the Organization

However, collaboration itself has been named as one of the grand challenges for visualization. Raje et al. (1985) define collaborative visualization as *"enhances the traditional visualization by bringing together many experts so that each can contribute toward the common goal of the understanding of the object, phenomenon, or data under investigation."* Therefore, in facilitating CCA, it is crucial to tackle the challenge of collaborative as well. According to Isenberg et al (2011), extending the visualization to facilitate collaboration would clearly go a long way towards increasing the scope and applicability of visualization in the real world. However, the emerging field of collaborative visualization is intrinsically interdisciplinary in nature, incorporating well-established research fields such as distributed computing, human-computer interaction (HCI), and, in particular, computer-supported cooperative work (or CSCW). Hence, Isenberg re-define the collaborative visualization as "*the shared use of computer-supported, (interactive,) visual representations of data by more than one person with the common goal of contribution to joint information processing activities.* Furthermore, she emphasizes the needs to identify specific challenges to address in the research space intersecting collaborative work and visualization as summarized in Table 2.3. For this particular research, we believe that the challenges will become more specific due to the intersection of collaborative work, visualization and complex cognitive activities domain.

Table 2.3 Specific Challenges to Address in the Research Space Intersecting Collaborative Work and Visualization (source: Isenberg et al. 2011)

Aspect	**Collaborative Visualization Challenges**
Users	Multiple participants
Tasks	Collaborative Activity Centric
Cognitive	Collaborative foraging & Collaborative sense making
Results	Consensus, shared insight
Interaction	Multiple input
Visual representation	Multiple display, novel display and input technology.
Evaluation	Social interaction

This research focused Collaborative-CCA on the activities category which occurs at a high level and is often complex and open-ended (e.g., problem solving, decision making, and forecasting). Although there are numerous CCA that can be performed, some of the more common ones is problem solving, decision making, strategy planning, concept learning, analytical reasoning, sense making, forecasting, knowledge discovery and learning (Sedig & Parsons, 2013). In this LR, we are mainly concerned to characterize three of the main CCA which regularly occur in collaborative settings in the organization, which are: i) Problem Solving, and ii) Decision Making. The paragraph below will descibe the Collaborative-CCA in details.

i Problem solving

Problem solving is the solution description situations in which individuals have goals but lack obvious ways of reaching them. Well-defined problems have clear goals and straightforward paths for reaching them; the goals for ill-defined problems are ambigiuous and the means of attaining them aren't clear. According to Jonassen (2008), a problem is a gap between two information states that should be bridged. In this way, the problem solving is concerned with searching through an information space to discover a path that connects a current state of information to some desired of a goal state. However, due to human cognitive limitation with regard to the amount of information that can be processed in working memory, problem solving is often a step by step process of connecting a current state to a sub-goal and eventually reaching the desired goal. According to Greiff et al. (2012), problem solving typically begins by constructing a mental representation of the information space. As an example, a set of

possible states of the problem, the current state and possible goal state as well as identifying the possible actions that can be performed to bridge the gap between information state.

Problem solvers use strategies to reach desired goals or sub-goals which involves changing their internal, mental representation or changing external representation. Experts in any domain have well-developed schemas that help to accommodate the limitations of working memory. They organize knowledge into complex schemas that allow them to represent problems as “chunks” and process problems automatically. In addition, their vast experiences help them to be metacognitive about their problem-solving efforts. Otherwise, novices often represent problems in isolated pieces and don't monitor their efforts effectively. Therefore, it is important to help users become better problem solvers by supporting them to understand and acquire the problem-solving strategies like an experts.

ii Decision making

Decision making is the process to identify and choose alternatives based on the values and preferences of the decision maker. It is a cognitive process to produce a final decision that may prompt an action. The process of decision making is generally by applying an explicit and tacit knowledge in a given area to make informed decisions. There are six steps to make the decision: define the problem, establish all the criteria, consider all the alternatives, identify the best alternative, implement the action plan and finally evalute the solution by examining the feedback (Guo, 2008). However, the process of decision making is not linear and straightforward. The decision making is basically based on human performance and environmental consideration. More over, Goldfrey-Smith (2002) mentioned the increased of complexities of the decision making in the complex environment since it has a large number of different possible state that cause higher cognitive function and processess. This cause information overload that burdens the decision makers’ cognitive process. Without guidance, the analysis within this context can become paralyze which effects the outcomes. In the collaborative setting, the situation becomes more critical since it increases cognitive

and personal biases (as an example, underestimating uncertainties, choice-supportive bias, cognitive inertia and sunk-cost fallacy bias).

2.4 COLLABORATIVE-CCA PROCESS [WHEN]

Markus et al. (2002) emphasized the importance to facilitate the Collaborative-CCA is during the process. It is crucial when the users need support to handle situation that is ill-structured or ill-sequenced has complex requirement is distributed across people, evolves dynamically and is unpredictable of job roles or prior knowledge. Nevertheless, they are different perspectives of the collaborative process. According to Isenberg et al. (2011), the collaborative visualization can occur in many scenarios delineated according to space and time that are related to CSCW as shown in Figure 2.3. Due to the consideration for the CCA context of use, this research limited the collaborative research on the basic category face-to-face collaboration that happens at the same time of synchronous and same space of co-located (e.g: meeting room, class room and lab space).

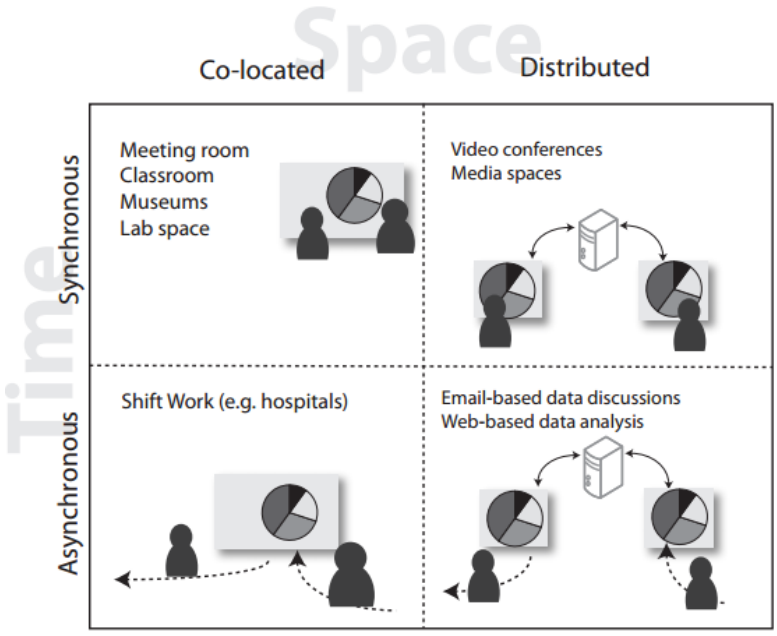


Figure 2.3 Collaborative-Visualization Can Occur in Many Scenarios Delineated According to Space and Time (source: Isenberg, et al. 2011 citing Baecker, 1993 and Dix et al, 1998)

Moreover, the research emphasized that the visualization design for face to face Collaborative-CCA must be able to engage the teams for viewing, interacting and

sharing. According to Isenberg et al. (2011), viewing is the process to support a collaboration to view static or animated visualization of data without being able to interact with or annotate the information (e.g Power Points and simple video conferencing tools to support the classroom or summarize the information for a larger group). Due to the current use of representation software, we believe that Collaborative-CCA in the organization need more than viewing. They need the visualization as a mediator that is able to let them interact and share the data in a wider visual context. Furthermore, these kind of engagement is important to guide them to create and develop knowledge during higher level of cognitive processes.

Distributed computing, HCI and in particular CSCW are among well-established research fields that helped us understand and define collaborative visualization. However, we can see that the contribution and effect towards the collaborative visualization field are more on the technological point of view. While handling the Collaborative-CCA process, there are many challenges, aspects, and issues that are unique to the intersection of Collaborative work, CCA and visualization. These are the places where researchers have to play a significant role in expanding the state of the art and help to shape when, why and how visualizations will be used in facilitating the Collaborative-CCA process. Aligning with Isenberg's point of view, we found the importance to derive a higher level of understanding when facilitating collaborative-visualization for specific use like in the case of CCA. While the previous research mainly discussed about how the computer-supported visualization to facilitate the collaboration, the visualization researcher should derive a higher level of understanding by developing an understanding about why the collaboration need a certain way of facilitation. By addressing the dedicated collaborative visualization challenges and requirements, the visualization can learn more about how to design interactions and representations to specifically support collaborative for knowledge creation and reasoning. By studying these needs in depth – identifying the goals and outcomes of the collaboration and how the users reason and information and knowledge formation are affected by visualization use - we will be able to apply the technological point of view that best contributes and applies our visualization knowledge and expertise. Therefore, to develop a higher level of understanding in providing visualization facilitation for Collaborative-CCA, first we

need to clarify who is the collaborative-CCA user and what they are doing during the Collaborative-CCA process.

2.5 THE COLLABORATIVE-CCA USER AND ITS ACTIVITIES [WHO]

The research intended to understand the Collaborative-CCA process through an understanding of its users and the activities they are doing. According to Huang (2013), human centric visualization emphasized the importance to understand why human (users) need the visualization hence enhanced the way on how visualization can best facilitate them. It is based from Human Centered Design (HCD) as the process to ensure the people's need are met (Norman, 1993). It has emphasized an effective design by solving the right problem and by doing so, it is capable to meet the human needs. Two important components in HCD are to identify the right problem and to find the right solution based on the double diamond diverge-converge model (Norman, 2005; 2013) as shown in Figure 2.4. The first diamond of divergence to convergence is meant to discover and define the right problem while the second diamond of divergence to convergence is meant to develop and deliver the right solution.

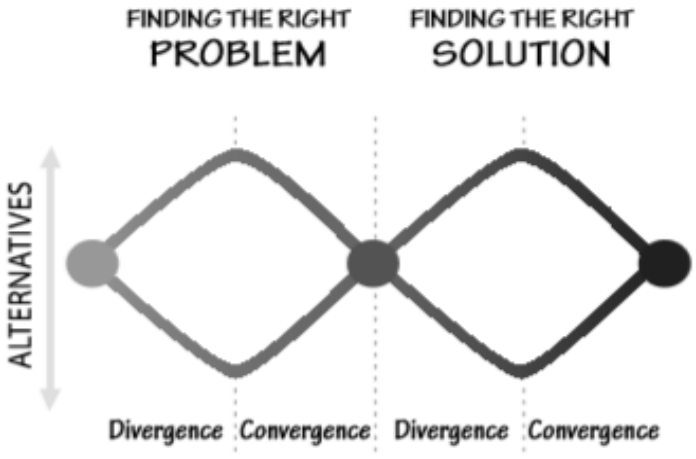


Figure 2.4 Two Important Components in Human Centered Design (source: Norman, 2013)

Due to the collaborative perspectives, the focus in this research is the addition of participants beyond a single user. According to Isenberg et al (2011), having multiple users is what transforms the cognitive process into a collaborative one and gives rise

to its challenges. From CCA perspectives, the users are the people that are involved in the CCA process. According to Eppler (2006b) and Mengis & Eppler (2008), experts and decision makers are among the most potential users that are involved during the face-to-face collaboration in the organization. Especially to handle complex issues, the higher level management teams that hold the higher ranks, roles and knowledge always come in place. Apparently, the meetings, discussions and forums are among the familiar settings during the collaboration. By understanding the multiple people as the users, the research expected to further understand their difficulties during the Collaborative-CCA process.

However, focusing and centralizing only on a human (user) might lead to insufficient understanding of the root cause of the problem. The culture and geography can be the greatest shortcomings to generalize on user understandings. Besides that, people primarily think about what they want instead of what they need (Sauro, 2012) and they always change the thinking and requirements based on the context and situation. In order to develop a specific design by referring to the users alone might improve the design for some group of people at the cost of making it worse for the others. The more consideration that is tailored for any particular likes, dislikes, skill and needs of a particular target population, the less likely it will be appropriate for others. Thus, (Norman, 2013) suggest an Activity Centered Approach (ACD) to further define the design and its structure. ACD can be defined as actions taken by the users to achieve the desired goal and has its theoretical underpinnings in Activity Theory. Since ACD is an enhancement from HCD, there is still an understanding of people but it also requires a deep understanding of the technology, tools and the reasons for the activities. This research intended to further investigate the Collaborative-CCA process situation by understanding the users-activity from the perspective of ACD. We intended to identify the dynamic sequential operation underlying the processes' activity to improve the ill-supported structure because most of HCD seem centered around static understanding of each set of controls. Furthermore, ACD is relevant to CCA since Norman (2013) defines and differentiates the term of activity as opposed to task, action and operation (events) that are in line with the four levels of CCA by Sedig & Parsons (2013). Thus embedding ACD during

the design process can potentially help for a better understanding the Collaborative-CCA process.

Through the design perspective, the research is not directly trying to solve the Collaborative-CCA process, instead we intended to discover the real problem by firstly understanding who the user is and their activities that lead to the users' difficulties during the process. By mapping back the user-activities problem and design, we hope to accomplish a design solution that is able to handle the users' conditions and their sequential activities during the Collaborative-CCA process. Norman (2013) has emphasized the importance to discover the real problem as he said *"Engineers and business people are trained to solve problems. Designers are trained to discover the real problems. A brilliant solution to the wrong problem can be worse than no solution at all: solve the correct problem"*. Even though the design perspectives seem to be going backward by revisiting the problem, it is crucial since the visualization design especially for the Collaborative-CCA process is in lack of it. The next section will further explain the discoveries about the real problem.

2.6 THE CHALLENGE OF COLLABORATIVE-CCA [WHY]

One of the problems in discussing the 'why' situation is we do not yet have the clear root cause of the problem between the intersection of the CCA and Collaboration challenges. Even though the research has found some cues for the CCA and Collaboration challenges in isolation, the coexistence between these two is still new and needs some further exploration. Using 5Whys approach (Norman, 2013; Sondalini, 2014), this research will further shown the 'why' challenges for CCA and Collaboration. This approach aims to identify the root cause of the problem by repeatedly asking and answering the question 'why'. Each question will be provided with the answer, evidence and solution (if any). Then, each answer will form the basis for another question in the following step. Even though the 5Whys seem too basic, they have proven to be sufficient to layer out the symptom in identifying the root cause of the problem. These techniques can be presented by using a tabular format or an Ishikawa diagram (backbone).

This research presented the whys using the Ishikawa diagram as shown in Figure 2.5. The row above provides the ‘why’ layer detailings from the CCA perspectives, meanwhile the row below provides the ‘why’ layer detailings from the collaboration perspectives. Finally the box at the end of the diagram present the intersection challenges between CCA and Collaboration that need further investigation.

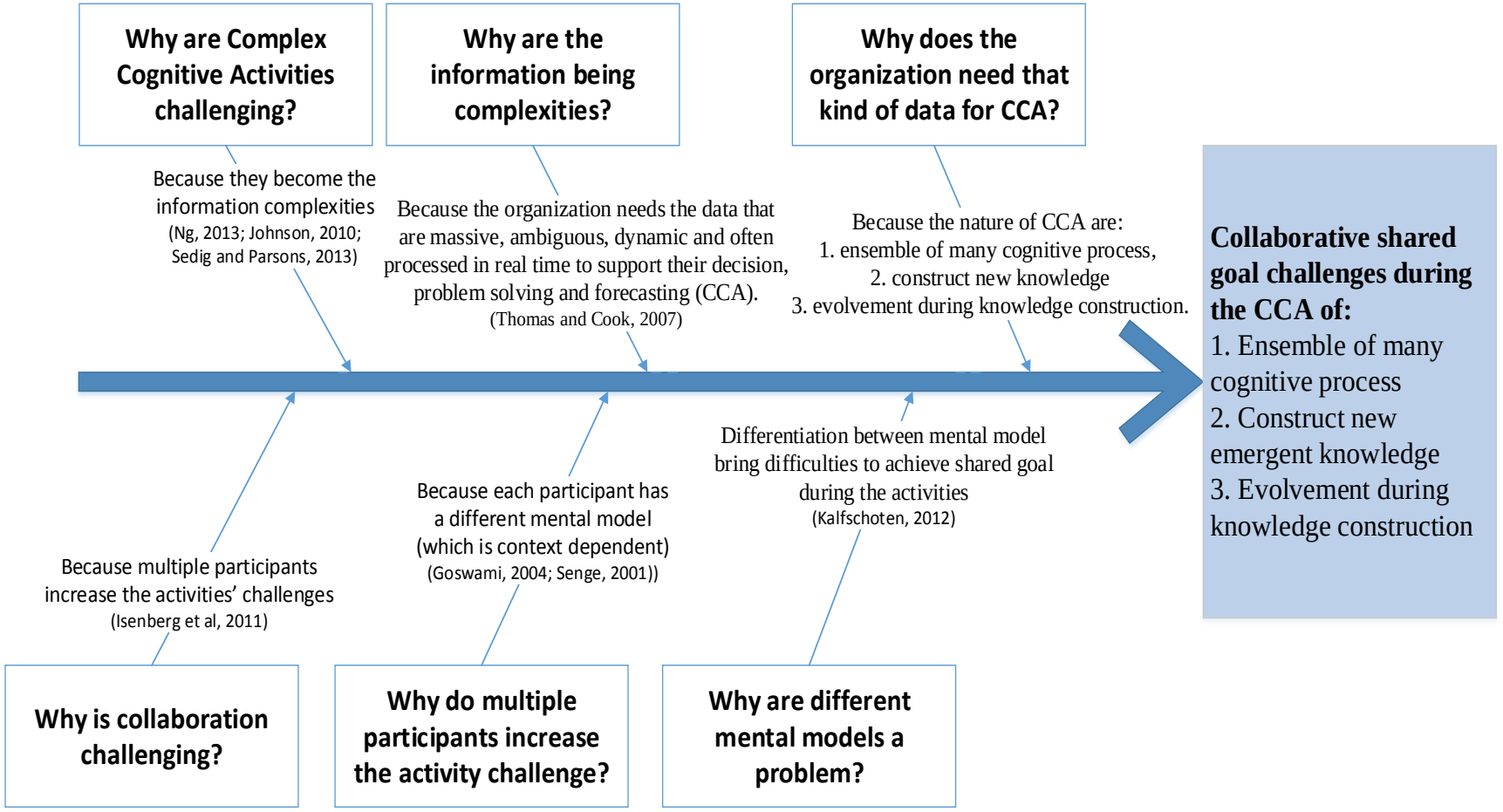


Figure 2.5 The Fishbone Ishikawa Diagram to Understand the Challenges from CCA and Collaboration Perspectives

2.6.1 Challenges from CCA Perspectives

Previously, the complex discussion in section 2.2.2 has clarified the information complexities for CCA from complex perspectives. In this condition, CCA need data that are massive, ambigous, dynamic and often processed in real time since the nature of CCA is context dependent, emergent and evolving throughout the time. Furthermore, from the CCA point of view, Table 2.4 is the summary of the challenges and the next paragraph will explain details for each of it.

Table 2.4 Summary of the CCA Challenges in the Organization

No	The challenge of complex system	The challenge of complex cognitive activities (CCA) in the organization
a.	Ensemble of many elements	**Ensemble of many cognitive processes** Many cognitive processess occur from a higher level of cognitive (e.g analyze, synthesize, evaluate and create) that emerge from availability of information.
b.	Emergence	**The construction of new Knowledge as the CCA emergence** Emergence of knowledge from interconnection between information elements from multiple sources, level of depth and abstraction and relevancy to the goal of CCA
c.	Evolution	**Evolvement during the process of knowledge construction** The dynamic and evolving of cognitive process incur the cognitive overload over the time.

a Ensemble of Many Cognitive Processess Within a Mental Model.

In CCA, there are many cognitive processes that occur during the process of CCA. Cognitive processess can be defined as the performance of a composite cognitive activity as the result of perception, learning and reasoning. The activity can be analyzed at multiple level of granularity – activity, task, action and event. Moreover, in the case of CCA, the cognitive process is mainly involved with higher cognitive processes (e.g analyze, synthesize, evaluate and create) that emerge for the availabity of knowledge. Hence, the capability to put the knowledge in use is dependent on the capabilities of the human to see the interconnection between various information available with the problem in hand. In the organization settings, the availability of information also take place in the complex conditions. The information comes from multi-sources, various levels of abstraction and details.

To create the best support environment in CCA, Sedig & Parsons (2013) propose the understanding for each of the elements that contribute to the CCA. Therefore, in supporting the CCA, it is important to understand the CCA type and processes, then analysze each of the task, action and event occuring within it. In these kinds of complex situations, there are four type of cognitive biased that will cloud the judgement which are self-serving biased, cognitive fluency, Sunk cost fallacy and confirmation biased. Since complex is a non-linear system that opens for uncertainty and bounded reality, it leads the user to be unable to make decisions based purely on rational analysis as in a linear model. The cue from the context is essential to help them to make the decision based on the complexities theory and context dependent model. Further than that, self awareness is essential to handle the CCA under uncertainty. By making people realize the real and general condition, they are aware and able to monitor their thinking compared to the reality one. This will help to reduce the self-serving biased. By being with things that make people grounded is the way to make people realize the real condition.

b The Construction of New Knowledge as CCA Emergence

In CCA, the challenge of emergence occurs due to the capability of the human cognitive process to construct the new knowledge that is usable for its context. The new knowledge from the perspective of organizational CCA is like a solution, idea, suggestion or decision. As this is a complex situation, the emergence of CCA knowledge through the cognitive process is more difficult because the user must be capable to:

- Understand the goal of CCA
- Extract the information
- Develop an understanding about the interconnections between different elements of information and identify the reasoning for each of the relationship.

By understanding the relationship and rationales between various elements, the user will be able to interpret new ideation and knowledge. The construction of new

knowledge will start from identifying and connecting the relevant key points. However, the interconnection become a challenge since different kind of elements is come from different levels of depth and abstraction and multiple sources. Under complex circumstances, it may lead to loose thread of an issue in which the CCA knowledge emergence must consider the relationship between variety of sources, level of depth and relevancy to the goal of CCA,

c Evolvement During the Process of Knowledge Construction

There is a general trend in organization towards an emerging information not within their control. It is essential for an organization to respond and act according to emerging information items to stay relevant in the market. Thus the management teams need to process emergent information items, align with their organization vision and mission and construct new knowledge as the outcomes that bring values to both the organization and the stakeholders. During the process of knowledge construction as the CCA emergence, Ladyman & Lambert (2012) concern about the developing for the overall pattern and structures. In complex circumstances, the cognitive process is many and related to one another, yet it all happens in the user's head that bring to cognitive overload. The cognitive overload is due to the process to remember all the related information, then the user need to identify the interconnection between the information elements and develop reasoning for each of the relationship. Since the cognitive process is dynamic and incurring over the time, then the impact of deviation from the actual goal, lost of guidance and memories will decrease the potential to lead for another knowledge emergence.

2.6.2 The Challenges from Collaborative Perspectives

From the organization perspective, we found the essential of collaborative setting while performing CCA. Generally, for CCA to arrive at any decision, the CCA process requires the views of multiple participants (usually experts from different areas within the enterprise, with different expertise, and are familiar with their own ways of data representation and analysis). Collaboration is an essential for productivity and innovation in organization. Collaboration implies a team to perform a

task jointly, thus requiring interaction and coordination of cognitive effort. Collaborative activities often require a high level of cognitive (Kolfschoten & Brazier, 2012). Moreover, as an organizational management system is increasingly complex and dynamic, the collaboration between the higher level executives and top management has to deal with increasing of complexities and different mental model challenges during the activities. Each mental model perceives a different value that is biased on their own interest. Thus, by having different mental models and a very specific view on the issue, the users are often not able to appreciate the shared goal that is worth to everybody in the collaboration and at the same time achieve the real value during the collaboration.

2.6.3 The Intersection Challenges between CCA and the Collaboration

Through an understanding of CCA and collaboration challenges above, the research assumed the intersection challenge is mainly for the collaboration to achieve a shared goal during CCA which is the ensemble of many cognitive processes, which needs the construction of new emergent knowledge that evolve throughout the Collaborative-CCA process. However, the research is still unclear about the factors that cause these intersection challenges that bring values to the Collaborative-CCA process in the organization. The research knew that the realization of visualization becomes real and meaningful only to the people who are aware of this subjective knowledge. That is why, it is essential to understand how the visualization is visible to one's eye shall be consistent to the understanding of why visualization is visible to one's mind. Therefore, this research intended to further explore the challenges of Collaborative-CCA Process. By understanding the challenges from both collaborative and CCA perspectives, this research intended to investigate the most effective way to facilitate it.

2.7 VISUALIZATION DESIGN PROCESS FOR COLLABORATIVE-CCA [HOW]

From previous LR findings, the research clarified the intention to develop a visualization design solution for the Collaborative-CCA process in the organization. In order to guide the process of visual design, the research was trying to find the most

appropriate visual design process that is in line for specific use that supports human-activity centric visualization. However, the research found the inadequacy of visualization design process since the focus is more on the function and operational and lack of rationales for design decision.

In terms of design guidelines and methodologies, the visualizaton field is still left behind (Craft & Cains, 2005, 2008; Moere & Purchase, 2011; Chen, 2005). Despite the increasing number of sophisticated and novel visualization techniques and methods, little is known about the design rationales that drove their design decisions (Sedig & Parsons, 2013). Craft & Cains (2008) clarify that methodologically, IV fields still lack proper guidelines for the visualization design process and are left to consult design examples, guidelines and reference models which do not adequately describe the visualization design process or suggest ways to undertake the process. Despite the increasing number of sophisticated and novel visualization techniques and methods, little is known about the design rationales that drove their design decisions. According to Moere & Purchase, (2011), there is an approach in designing visualizations namely ‘genius design’ in which the designer takes the role of an absolute authority with natural instincts, knowledge and skills to produce a considered desirable experience. Although there is a need for a greater role for designers, it is not so simple and the ‘genius’ needs to be supported systematically. It has been years since an IV scientist requires a stronger role for good scientific reasoning to guide visualization research components (Bertschi et al. 2011). It happens where visualization is in dilemma to put more concern on the cognitive perspective, since it is rooted from the computer science field, the preference is more on pragmatic that refers to the technological and mediatory aspect and is mostly practised by people from that background. Thus, the elements of human centric like cognitive, perceive and communication that are in the forms of abstraction, uncertainty and complex are still in dilemma to be a logical and scientific rationales in designing IV.

These shortcomings also can be seen from the syntheses of IV by Chen & Floridi (2013). The study has shown such a concern for understanding the context of use as a rationale for visualizations helps to make them more effective. Visualization pipeline from the synergies perspectives between information theory and philosophy

of Information (Floridi, 2010) has synthesized the two semantic context of viewing and seeing corresponding to different parts of a visualization pipeline. From here, they emphasize the importance of continuity from the outcomes of 'viewing to one eyes' to 'seeing to one mind' in the visualization pipeline. However, as a computer supported tools, the process of visualizing is focused more on 'visible to one's eyes' in the Human Computer Interaction (HCI) and less concern about the process of 'visible to one's mind' in the Human-Human Interaction (HHI) context. Thus the literature in visualization-computer supported tools are more on the process of enriching, filtering, mapping, rendering, displaying and viewing the visualization. As it is rooted from the computer science field, the research in the visualization field is focused more on the functionalities element rather than the context as a whole. IV is concerned more on HCI instead of HHI perspectives. Even in the early days of IV – the classical visual information-seeking mantra is *Overview first, zoom and filter then details on demand* by Schneiderman (1996) concerns more on taxonomies, which they offered a task by seven data types taxonomy while Chi (2002) developed Data State Reference Model that has hierarchical techniques based on similar system operating steps. Even the basis of visualization pipeline (Card, et al. 1999) has inspired a visual design process (North, 2005), Nowell (1997) and Daassi et al. (2004) but the process is focusing more on visual mapping from raw data to visual space, form (glyph, presentation) and properties (Nowell, 1997; North, 2005; Card & Mackinlay, 1997).

Less focus on the HHI context leads to less concern for the process of understanding human perceivedness in the visualization field. We are still lacking on guidelines for the process of viewing the visualization as knowledge for the users. This is the missing link especially when visualization has the intention to facilitate complex activities in the collaboration settings. Showing the example of understanding the real needs of visualization by putting more concern on the context of user, Drocourt (2011) shows the concern of understanding the context of visualization usage as a rationale for visualization to work effectively. In the collaborative settings, the concern on the context must be custom as the group-fit since the collaboration must handle the varieties of users' functions, roles, knowledge and mental model. In their study, they have relied on the real needs of glaciologists by including the context of use and how they work in the real world environment. From

this example, it shows the needs to understand the visualization context of use is important to make it visible to one's mind. It also found out how to enable the glaciologists to link their mental spaces using a shared representation space.

2.8 LITERATURE OVERVIEW AND RESEARCH DIRECTION

Visualization has evolved from displaying visual forms to conceive knowledge in human mind. After more than 30 years of advancement, visualizations have become very important, almost indispensable and are used in many application domains. As a result, we can see the trend of visualization use has been expanding rapidly and moving towards specific and special application in various domains. Recently, the visualization has paid attention to support the organization in decision making, analyzing, forecasting, problem solving and strategizing - which is in a larger extent called Complex Cognitive Activities (CCA). However, we found the lack of CCA understanding in the collaborative settings that might mislead the visualization support. Therefore, by focusing on visualization design perspectives, this research intended to further understand the Collaborative-CCA phenomenon in order to develop an effective visualization design solution for it. Through LR, the research further investigated how the current visualization handle the Collaborative-CCA phenomenon by following 5W and 1H techniques. The findings throughout the LR has been summarized in Figure 2.6.

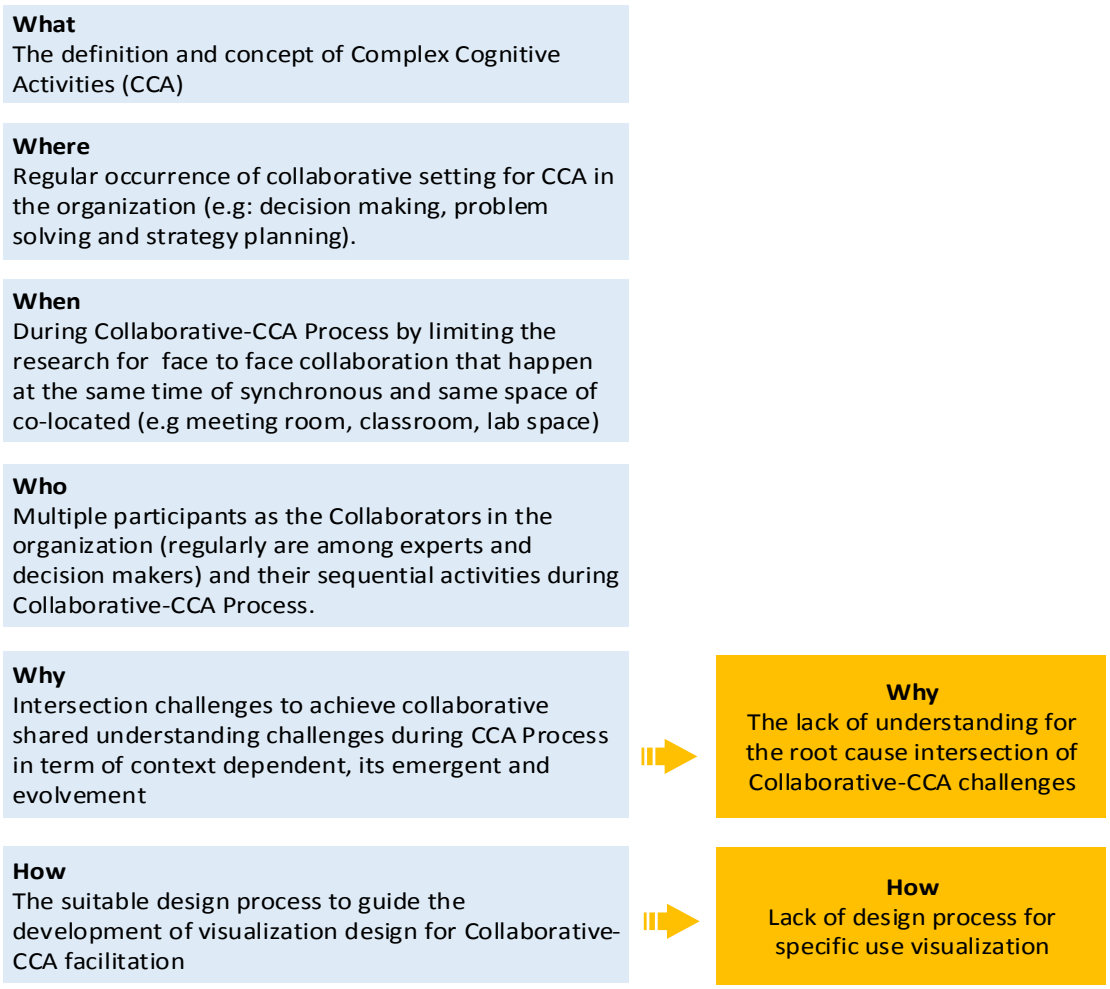


Figure 2.6. The Summary from LR

From the summary above, we can see that the first 4W (‘what’, ‘who’, ‘where’ and ‘when’) is informing us the scope for the Collaborative-CCA visualization design. From the ‘what’ perspectives, we now understand the approach in tackling the complex cognitive challenges is not straightforward like handling the simple cognitive process. By knowing that CCA regularly occur in the collaborative settings of the organization and the process is when the facilitation is needed most, then the research has realized that the challenges occuring in Collaborative-CCA are beyond the cognitive memories of storing and encoding. The solution is not only about reducing cognitive load and its information processing as regularly mentioned in the simple cognitive research, hence visualization design must consider the difficulties faced by multiple participants and their activities during the Collaborative-CCA process.

Nevertheless, the LR also clarified some shortcomings from visualization perspectives to design a specific and special application like the Collaborative-CCA facilitation in terms of the: (i) 'why' perspectives - the lack of understanding for the root cause for Collaborative-CCA problem, and (ii) 'how' perspectives – the lack of design process for specific use that support human-activity centric visualization. Each paragraph below will further describe these shortcomings:

(i) In term of the 'why' perspectives, the LR found the lack of understanding about the root cause of the Collaborative-CCA problem. Even though, some researches have emphasized the problem of increased complexities are due to complex matter and multiple participants and we found the significant roles of visualization reduce the analytical processes from the information complexities, there is still a lack of understanding for the collaborative settings during the CCA process. Although there has been some realisations of the need to cater the visualization for collaboration, the research in this area is still at the early stage and not focusing on CCA (Isenberg et. al, 2011; Sedig & Parsons, 2013). Using the Ishikawa Diagram, the research found the conjunction of collaboration challenges to achieve a shared understanding during the Complex Cognitive Activities in terms of the incoming of context dependent, its emergent and evolvement of the information. Therefore, it is important to further investigate these conjunction challenges to have better design decision rationales as to facilitate and manage the Collaborative-CCA process.

(ii). In terms of the 'how' perspectives, the LR found inadequacy of the visualization design process to guide specific use visualization. From HCD and extension to ACD perspectives, the research intended to understand the users and their activities as a basis to support visualization design rationales. On top of understanding the user, by carefully studying the activities which needs to be done by the users during Collaborative-CCA might potentially lead to understanding the root problem of its challenges. In this case, the research are not directly trying to develop a novelty design for the Collaborative-CCA problem, instead we intended to understand the root cause of Collaborative-CCA problem and then rationalize the visualization design solution. From the summary findings as shown in Table 2.5, the research found the lack of

human-activitiy centric visualization since the focus is more on function and operational and lack of rationales for design decision.

Table 2.5 The LR summary for Current Visual Design Process

No	Sources	Description	Summary
1	Schneiderman, (1996)	Classical visual information seeking mantra – overview first, zoom and filter then details on demand	Concern more on tasks and functionalities
2	Nowell, (1997)	Visualization mapping from raw data to visual space, form (glyph, presentation) and properties	Focus more on visual mapping (raw data to visualization) and operating steps.
3	North, (2005)	Visualization pipeline	
4	Chi, (2002)	Data State Reference Model	
5	Craft & Cains, (2008)	Design guidelines and methodologies in the visualization field is still left behind. Left to consult design example, guidelines and reference model which do not adequately describe the visualization design process.	Inadequacy of visualization design process.
6	Moere & Purchase, (2011)	Approach of 'genius design' in visualization. Designer takes an absolute authority that need to be supported systematically.	'Genius design' need to be supported systematically
7	Bertschi et al. (2011)	Human centric elements (e.g. cognitive, perceivedness and communication) in a form of abstraction, uncertain and complex are still in dilemma to be accepted as logical and scientific rationales in visualization.	Human centric elements is still in dilemma to be accepted as logical and scientific rationales in visualization.
8	Sedig & Parsons, (2013)	Despite the increasing number of sophisticated and novel visualization techniques and methods, little is known about the design rationales that drove the design decisions	Lack of rationales for design decision.
9	Drocourt et al. (2011)	Concern of understanding the context of visualization usage as a rationales for visualization to work effectively.	Lack of guidelines for the process of viewing the visualization to be knowledge for the users.
10	Chen & Floridi (2013)	Emphasize the importance of continuity from 'viewing to one eyes' (visualization coding) to 'seeing to one mind' (knowledge value of visualization to the human).	

2.9 CONCLUSION

Despite the increasing general interest in visualization design and its related concepts, the specific use visualization concept was mainly investigated according to the context definition. Many scholars in this area are aware of the lack of visualization to handle this kind of design and have called for more researches. Accordingly, limited studies have explored the visualization from the perspectives of collaboration or CCA but a

lack was reported of the intersection of Collaboration and CCA. The construct of these visualization designs may demonstrate the generalization in its multiple context of use, but there are gaps in our understanding of how visualization need to be designed in increasing complexities of Collaboration and CCA. From the LR findings, we can conclude that, even though the intersection between CCA and Collaboration is widely known and noticed in the organization, it has been taken in general and less in coexistence by the visualization field. Hence it is needed most to be understood in order to develop better facilitation for visualization in the organization. This major gap in understanding the Collaborative-CCA for more useful visualization design has become the focus in this thesis.

Therefore, this research aimed to develop an effective visualization design for the Collaborative-CCA process in the organization. For this kind of specific use visualization, the human-activity centric emphasize the understanding for the root cause of Collaborative-CCA challenges that can help to rationalize the visual representation design and then the evaluation to justify the effectiveness of the design. Further exploration for this research is by considering the findings from the LR:

- The research will start the exploration of Collaborative-CCA from current condition found in the 4W (‘what’, ‘where’, ‘when’ and ‘who’).

- Due to inadequacy of specific use for visualization design process in the ‘how’findings, the research is considering to apply the more general methodology that focuses on design and is suitable with the Collaborative-CCA context. Design Science Research Methodology (DSRM) seems to be the suitable methodology and this issue will be further elaborated in chapter 3. Furthermore, in order to understand the rationales of design decision, this research will concern more about design on the theoritical level (design theory development) instead of the empirical level (testing the design theories). Concurrently, the research intends to explore an appropriate design process for specific use visualization through the demonstration of the Collaborative-CCA design theory development.

- In terms of the lack of understanding about the root cause of the Collaborative-CCA problem in the ‘why’ findings, the research intends to identify the root cause challenge by considering the difficulties faced by multiple participants and their activities in the intersection between Complex Cognitive Activities and collaborative domain. This will be further explained in chapter 4.

This thesis is expected to fill some knowledge gaps by exploring the Collaborative-CCA process and these understandings will further rationalize the potential of visual representation design. Then the design will be evaluated in term of its usefulness to handle the identified Collaborative-CCA challenges.

CHAPTER III

RESEARCH METHODOLOGY AND DESIGN

3.1 INTRODUCTION

This chapter reports the methodological approach that governs the process to achieve the thesis' purpose: An effective visual representation design to facilitate the Collaborative-CCA process. Many have used the term interchangeabally when describing research design, methodologies and methods. In this thesis, we follow Creswell's (2003; 2009) terms, definitions and directions in order to eliminate the confusion. In conjunction with that, since the central attention in this thesis is visualization design yet the visualization field itself is lack of the suitable design process, we decide to apply Design Science Research Methodology (DSRM) that is generally used as the comprehensive and rigorous backbone to govern the research design especially in visualization larger extent – Information Science (IS) discipline. Futhermore, DSRM is suitable to guide and conduct visualization design since it has been congruent with the pragmatic philosophical worldview, supports an exploratory mode and is relevant to the complex activities' nature and collaborative phenomena neccessities.

Before further investigating further, presenting and alligning DSRM with this research. Firstly, this chapter will explain the research aim, philosophy and direction. Since the research is pragmatic, explorative and natural, the complementation of DSRM with various methods is essential. Therefore, the ROs will be alligned according to the phases of DSRM. Each of the objectives will be included to one or more DSRM phases. Then each of the RO will have its own process design and the selection of methods, participants, data collection, management and analysis will be described according to the objective targets.

This chapter is structured as followed. Section 3.2 will explain the philosophical, mode and research direction based on thesis statement, purpose and qualitative approach. The understanding from previous sections help to develop the research design for this thesis. The research design is the prime content and will be discussed in section 3.3. According to the 3 ROs, this section alligned DSRM's phases into 3 main activities. Based on the suitability to achieve their own goal and objectives, each of the activity is having different kind of research process design in which will further elaborate in details. Each of the activity will be discussed separately in section 3.4 (activity 1), 3.5 (activity 2) and 3.6 (activity 3). The communication for the research outcomes will be presented in section 3.7 and lastly, section 3.8 summarises the chapter.

3.2 RESEARCH DIRECTION

Research philopsophy, directions, methodologies, methods and research design have been discussed from various angles depending on the perspective of the research. This research follows Creswell's (2003; 2009) terms, definitions and directions in order to eliminate the confusion. Then, the understanding about the knowledge, aim, process and techniques used in this research have been developed according to that basis. Basically this research follow the pragmatic philosophy, exploratory methodology as to goven the research methods, DSRM as the strategy of inquiries and qualitative approach. In the next paragraph, this thesis will describe and answer these elements accordingly.

a Pragmatic Philosophical Worldview

This research has a pragmatic philosophy worldview. Philosophical worldview is a paradigm or a basic set of beliefs that guide action. It is based on epistemological and theoritical components (Creswell, 2003). Epistemological is the theory of knowledge embedded in the theoritical perspective, while theoritical is the philosohical stance-lies behind the methodology in questions. It influences the practice of research. Since the thesis states the concern about the solution design to the Collaborative-CCA phenomenon, this research is having pramatic philosophical view because the solution

should arise out of actions of the Collaborative-CCA situation rather than antecedent (as in postpositivism) or social understanding (as in constructivism) alone. Instead of focusing on methods, this research emphasized the real world practice and problem and used all approaches availabe to understand the Collaborative-CCA challenges and find a way to solve it. Thus, our research worldview is alligned with Creswell (2003; 2009) to convey the importance of focusing attention to the problem from the phenomenon and then using pluralistic approaches to derive a solution about the problem. Therefore, this research has freedom and is not committed to any system philosophy.

b Exploratory Sequential as to Govern the Research Methods

Generally research method is the way to get the data and information during the research. The most common ways are literature review, talking to people and observe the phenomena. Typically, the research method is tie up with the philosophy and strategy that govern the research. Therefore, based on the pragmatic philosophical worldview and DSRM, we intended to complement and mixed the research method as long as they can serve the research aim and objectives. Considering the timing by sequential that is connecting from the Collaborative-CCA phenomenon and weighting more on qualitative, based on Creswell's planning procedures, this research is having a sequential exploratory to govern the research methods since it is congruent to the thesis purpose - to develop the visual design solution because the existing solution is inadequate or not available. It is suitable for a phenomenon that has not been clearly defined. Since, we started by knowing a little about the Collaborative-CCA challenges and not to mention how to solve them, the exploratory research is seeking for a new findings.

c Qualitative Approach

For the overall research, this thesis is explorative and following inductive approach. It has aimed to develop a visual representation design as a new solution emerging from the research. Even though inductive orientation is generally associated with qualitative approach whilst deductive orientation is more commonly used in quantitative approach, there are no set rules that qualitative must only follow inductive orientation (Gilgun, 2010; Yin, 2010a; Gabriel, 2013;). Inductive is contradictory with deductive. According to (Gabriel, 2013) the main difference between inductive and deductive approaches is that whilst a deductive is aimed at testing theory, inductive is concerned with the generation of new theory emerging from the data.

In developing a new solution, we relied more on theories and LR to develop the foundation about the Collaborative-CCA phenomenon and its solution. However, we did find the importance of qualitative approach to expand and explain and justify the foundation in the real situation that concern more about human contextual in which they live and work (Creswell, 2009). Since this research need to understand users' cognitive, interaction and communication in the collaboration while handling the CCA, the qualitative approach is appropriate to observe the Collaborative-CCA in the natural settings. Other than that, qualitative approach is able to let the description, interpretation and justification for the underlying process of visual design. This convinces us that qualitative approach is capable to answer the rationales or 'why' questions throughout the visual process design. Therefore, this research will use the qualitative apporach deductively to verify, expand and justify the foundation from the theory and LR basis. Sampling and the qualitative analysis.

d DSRM as the Strategy of Inquiries.

Strategies of inquiries are the approaches, design or models that provide specific directions for procedures in a research design. In other words, the strategies of inquiries are also known as the research methodologies (Mertens, 1998). It is the strategy or plan of action that links research to govern the choices of methods (e.g, experimental, survey, ethnography). In this research, the central attention is about

visual design solution. Therefore, we chose DSRM as the methodology to govern this research (Hevner, 2007; Peffers et al. 2006; Geerts, 2011). The research found the relevancy of DSRM towards this research because it is alligned with the pragmatic philosophical worldview. According to Northcote (2012), many researchers are aware of the need to match philosophical worldview with research methodology. Since the pragmatic aim to solve the problem and DSRM share the same aim, then the selection of DSRM being able to make the research reach the aim is priority. Moreover, the research has acknowledged that the visualization field and IS as its larger context are applied research disciplines that apply theory, frequently from other disciplines. In this case, they are from social science, management, organization, collaboration and complex domain to solve problems at the intersection of computer supported visualization design and organizations. Further than that, descriptive and interpretive researches paradigm borrowed from other domain is resulting in inadequate research output and not often very applicable to solve the problem. Hence, the DSRM process involving theory development (design theories) and theory testing (kernel theories) offers an important guideline for conducting applicable yet rigorous in this kind of applied research discipline.

Due to the involvement of theory development and theory testing, this research relied more on Literature Review (LR). According to Creswell (2009), LR serves different purposes based on the research paradigm - qualitative, quantitative or mixed methods paradigm. In qualitative, LR is used to substantiate the problem while in quantitative, LR is used to suggest possible hypothesis but in mixed method (pragmatic), the use of LR will depend on the type of design. Being a pragmatic and theory-based research, LR played an important role in this research. Furthermore, Retroactive analysis from Geerts (2011) shows the significance of LR as the knowledge tools in most of DSRM activities. For the view of the fact that reflection from the current state of the art is essential, LR is a critical method to further investigate the previous research. It can be from various sources like scholarly paper from previous research, which includes current knowledge, substantive findings, theoritical and methodological contributions to a particular topic. Regularly, the brief summary from the major literature from any particular topic was able to give a point of view and current state-of-the-art understandings.

3.3 RESEARCH DESIGN

Research design is a detailed outline of how an exploration will take place in this thesis. The understanding from previous sections are to ensure this research design will effectively address the research problem and able to develop the visual representation design for Collaborative-CCA process. In order to do that, based on the three commonalities of DSRM phases, the ROs have being allign with the DSRM phases as summarized in Figure 3.1. The research design that has been provided in this chapter will guide to achieve the aim to develop visual representation design for the Collaborative-CCA process. Due to the pragmatic philosophy and sequential exploratory strategy, each of the activity will has different research design according to achieve the different outcomes that at a larger extent is interrelated with each other in order to achieve an effective visual design solution for Collaborative-CCA process. Each of the research design will be explain in the paragraph here after.

- Activity 1 (based on RO1) will mainly discussed in chapter 4. The research will identify the Collaborative-CCA challenges by LR and further verify through semi-structured interview. The verification in the real settings is not only meant for accountability but at the same time, lets us understand and describe the challenge from the real settings of collaborative-CCA.
- Activity 2 (based on RO2) will mainly described and prescribed in chapter 5. The outcomes from RO1 will be reflected from the visualization perspectives to provide the rationales and see the clearer roles for visual representation. This might lead to an effective of theory usage and theorizing during the visual representation design development.
- Activity 3 (based on RO3) will mainly explained in chapter 6. It will justify the usefulness and effectiveness of the visual representation design through demonstration and evaluation phases.
- Finally, communication phase will let the research to justify the contribution of the research outcomes towards the visualization fields and its users. As a conclusion, since the main outcome for this research is the design theory of visual design, then the outcomes from RO3 will reflect back and justify the RO2 in handling the RO1.

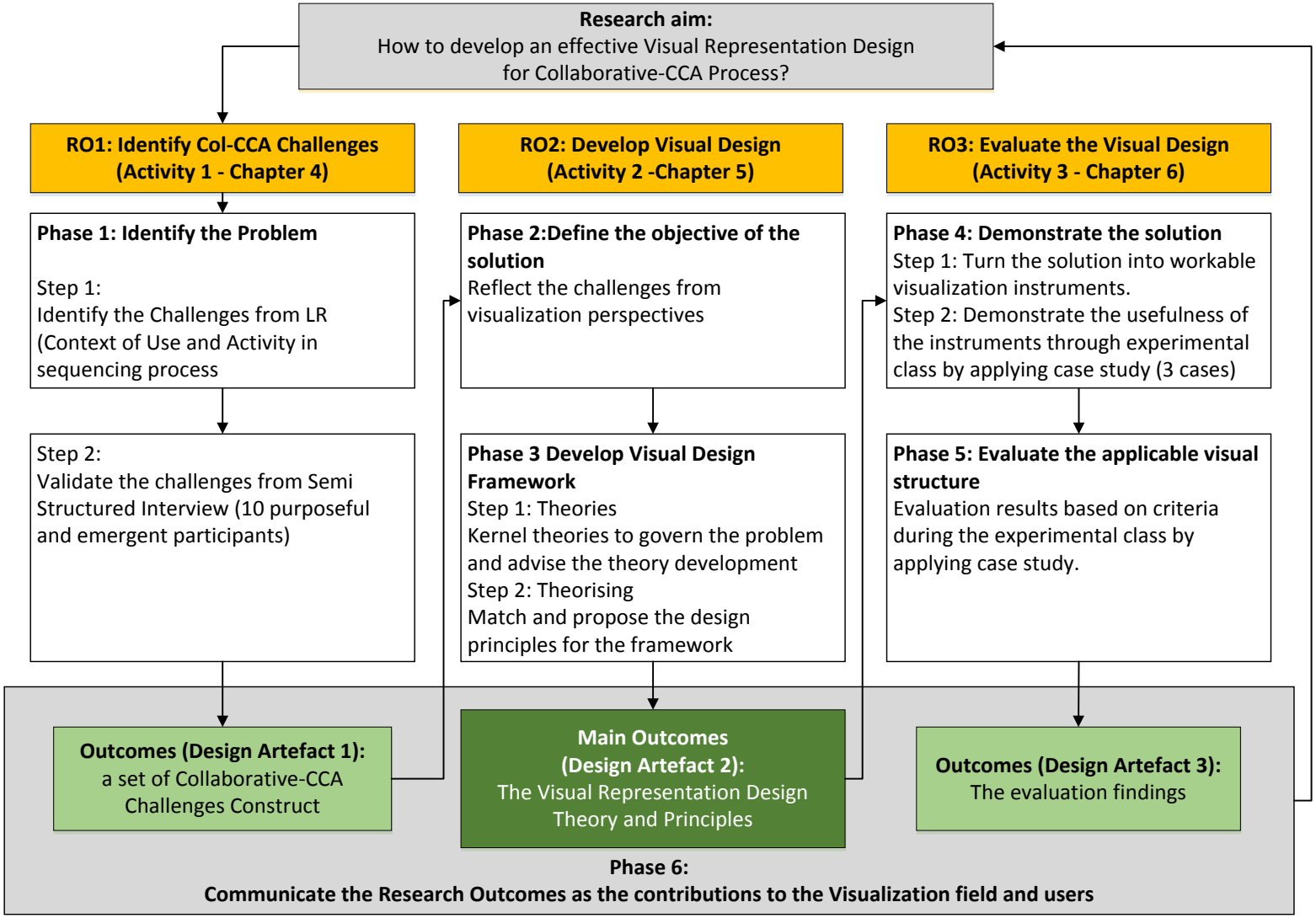


Figure 3.1 The Summary of the Research Design

In order to develop an effective visual representation design (VRD) for Collaborative-CCA Process, this research emphasize the credibility design towards two elements – effective and novelty. Figure 3.2 shows the mapping between the research activities and DSRM paradigm, From the diagram, the research inted to highlight the effective element due to its relevancy on the business and the novelty element due to rigor on the knowledge. Moreover, to justify the effectiveness, the evaluation will help from the perspective of design cycle. Hevner (2007) and Iivari (2007) highlight the three cycle view of DSRM to provide a clear and consistent understanding while communicating the design process. Therefore, by explaining the relevance, rigor and design cycle, this research intended to establish the design process credibility in developing VRD in which help to justify the contributions later.

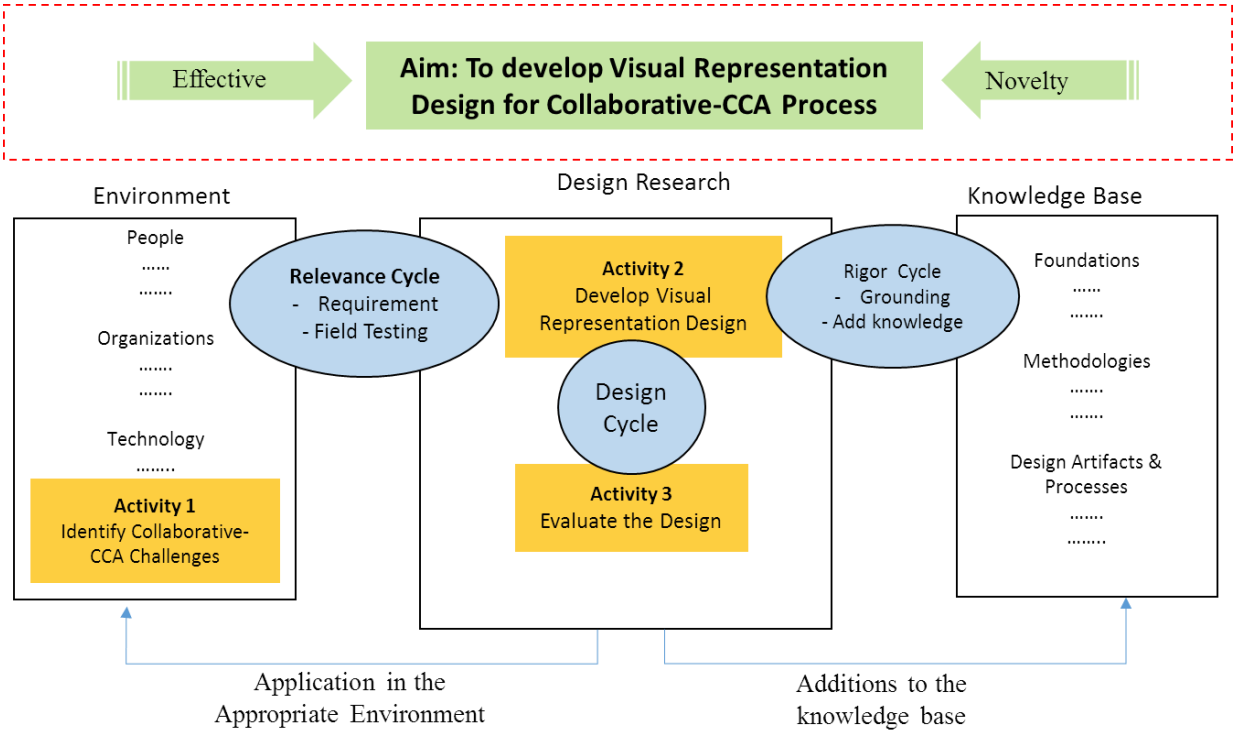


Figure 3.2 The Mapping of the Research Activities in DSRM Paradigm (adaptation from Hevner et. al (2004) and Hevner (2007).

3.4 ACTIVITY 1 - IDENTIFY COLLABORATIVE-CCA CHALLENGES.

Problem identification is aimed to define the specific research problem and justify the value of solution. It is the very first activity in the DSRM process. Peffers et al (2006) and Vaishnavi & Kuechler (2007) have mentioned about awareness of the problem as

the prerequisite in the DSRM process and Hevner et al. (2004) also agree on the necessity to see the problem as the motivation to move to the next activity. It also can motivate researchers to pursue the solution, help to understand the reasoning and rationales of the proposed solution and help the researchers to justify the value of the solution.

Since there is still a lack of consideration about collaborative users in CCA, it is still inadequate of the research to emphasize the significant problem within Collaborative-CCA that is able to justify the needs for a better design. Therefore, the research needed to identify the collaborative-CCA challenges from scratch, in which the research intended to expand the phase of the problem identification by embedding the methods of LR and verification as presented in Table 3.1. Through LR, the problem identification view researches from other areas to help us understand the root cause and then verify these findings through semi structured interview from the real settings of collaborative-CCA. In other aspects, the verification can enhance the credibility of the identified challenges to convince the visualization communities.

Table 3.1 The Methods and Settings for Problem Identification Phase

Purpose	**Knowledge Base**	
	Methods	**Settings**
a. Identify the foundation for Collaborative-CCA challenges.	Literature Review (LR) and Analysis	In knowledge domain of collaboration, cognitive and complex activities.
b. Verify the challenges.	Semi-structured interview	10 participants from the organization.

3.4.1 Literature Analysis to Identify the Foundation of the Challenges.

In order to identify the basis of Collaborative-CCA challenges is by reviewing LR. In appreciating and utilising the prior knowledge, LR seeks researches from other areas to help us through the discovery from various fields and perspectives such as complex system, cognitive, collaboration and management. However, due to the wide range of collaborative issue and this research is tended to centralize the challenges from the perspective of activities (Norman, 2013), we are following De Vreede et al (2009) on collaborative design structure. They suggest to get an overview of the collaboration

challenges from two perspectives – design and deployment. The design phase basically is the context of use. Since this research is concentrating in cognitive, it means to understand the background of the collaborative task, knowledge content and task context in order to have a meaningful, rightfully and able to achieve the cognitive-collaboration goal. Then, the deployment phase is more in understanding the collaborative process and activities. From here, the research should understand how Collaborative-CCA take place and why certain collaborative processes need to be supported (Jonassen, 2008).

3.4.2 Semi Structured Interview to Verify the Challenges.

The research verify the Collaborative-CCA challenges using semi structured interview from real organization settings. The necessity of verification is not only for accountability, but also to expand the understanding of the context of use and activities by getting a deeper understanding about how and why these challenges occur in the real Collaborative-CCA settings. If occured, then using description and task settings from the participants' own job perspectives, we hope to enrich and expand the description for each of the challenges and how it gives impact to their job and activities. The research expected the construct of challenges as the outcomes (design artifact) from this phase. We then aim to further produce and apply these outcomes to create an effective artifact for the next phase.

a The Unit of Analysis and the Criteria for the Verification

The unit of analysis for this study is the Collaborative-CCA Process. Based on the need to understand the activity and its sequential process, the research gained an understanding as to how Collaborative-CCA really works in the organization. Moreover, since we are focusing the study on the real setting organization of Collaborative CCA, then the qualitative analysis will be carried out deductively – DQA. By having the deductive approach, our investigation will become more focused on the cognitive since the themes have been identified from the previous LR. These themes will become the criteria for the evaluation as in the Table 3.2.

Table 3.2 Criteria, Unit of Analysis and Description for the Real Organizational's Verification.

Criteria	Description	Unit of analysis
Context of use and group-fit neccessity	• Distinguished background of collaborator lead to different mental model during the Collaborative-CCA process. i. Different roles ii. Different level of knowledge iii. Different social background	The Collaborative-CCA process
The lack of understanding and supporting the Convergence	• Understand the main driver i. No centralized guidelines ii. Difficulties to appreciate value of main driver iii. Difficulties to sustain the main driver direction • Understand the interconnection between elements in different level of abstraction and details	The Collaborative-CCA process
The evolvement during the process of collective knowledge construction	• The evolvement of collective input for the cognitive process. • The evolvement of collective output from the cognitive process.	The Collaborative-CCA process

b Sampling Strategies and Participation

The verification has 10 participants from purposive and emergent sampling strategies as mentioned in Table 3.3. In selecting the participants, the most important part is the strategy on sampling. Sampling is the process of selecting units from a population of interest. Purposeful sampling is well-described by Patton (1990) with variation of 16 types of it. For this study, based on Suri's (2011) suggestion to expand the qualitative synthese methodological possibilities, the research used the combination of 2 types of purposeful sampling strategy – the criterion and emergent samplings.

Table 3.3 Participants' Criteria and Selection

Criteria	Participants ID (PID)	Designation and Organization
Criterion Purposeful Sampling Strategy (5 participants)		
• Profesional/Managers /Executives/Grade A level • 10 years working experience • Management level in the organization (involve Collaborative-CCA process)	PID 1	Senior Sales Manager, Kaymarine Sdn Bhd.
	PID 2	Principal Assistant Secretary, Kementerian Kerja Raya
	PID 3	Human Resource Department Manager, Duta Marine Sdn Bhd.
	PID 4	Human Trafficking Affairs, Kementerian Dalam Negeri Account
	PID 5	Head of Policy Department, Jabatan Landskap Negara.

Emergent Purposeful Sampling Strategy (5 participants)		
• Sectretariat for any Collaborative-CCA process	PID 6	Sectretariat for ICT Steering Committee, Kementerian Kewangan.
	PID 7	Government Procurement Committee, Kementerian Kewangan.
	PID 8	ICT Secretariat, Jabatan Penilaian dan Perkhidmatan Harta.
	PID 9	Human Resource Manager, iPerintis Bangsar (ICT Petronas)
	PID 10	Cabinet Secretariat, Jabatan Perdana Menteri.

First is the criterion sampling as the foundation to select a representative part of a population for the purpose by determining characteristics from the whole population. As this research is designed to investigate more about activities that originate from the domain of management in the organization, the first criterion is the activities must be in the collaborative-CCA condition, thus we chose the participants that have experiences in performing Collaborative-CCA from the organization as the participants. From the organization domain concept, we selected participants based on Mengis & Eppler (2004), Mengis (2007a; 2007b; 2008) and Eppler (2012) which carried out the investigation among a management team in the organization. In this case, the participants are from expert or decision maker backgrounds in the organization. Five (5) participants were interviewed from the public service and corporate agencies in Klang Valley, Malaysia as they met the requirements of the criteria listed below:

- The participants must have an experience in performing Collaborative-CCA in the organization. Thus, most of the participant were at the Professional/ Managers/ Executives/ Grade A level. This group is mostly involved in the management team of organization. Thus, it involves the process of complex activities like problem solving, strategy planning and decision making in the collaborative settings. The selection mostly within this level can eliminate issues of different education and working background.

- The participants had more than ten years of working experience. The data collection needed to obtain the perspective of the management team and how they collaborate while handling CCA. Participants with this range of working

duration are well experienced and mostly experts who influence decision making, with some of them having been promoted to the management team (decision makers).

During the interviewing process with 5 participants in the criterion sampling above, the research still found the lack of description about the Collaborative-CCA phenomenon. We found some prejudices and biased instances since the participants were involved in specific domain and more on determined-complicated activities instead of the uncertain-complex one. In the meantime, the early findings from 5 participants have showed the major roles of the secretariat to handle the Collaborative-CCA. The participants mostly mentioned the importance of the secretariat roles since they manage the committee before, during and after the meetings. Thus, the research employs the emergent sampling strategy as the second type of strategy to investigate further from secretariats' point of view.

Emergent sampling strategy occurs in this research when we decided to take another five (5) secretariats as the participants during the process of collecting data. Along with this, the researcher also gain 'how knowledge' for the better sampling selection due to the human-activities paradigm. As this paradigm is to understand the 'why' question, asking the people who participated in the activities is useful to describe their experience. However, it might end up with biased responses since the participants are more about describing their personal point of views and sometimes, they have limited perspectives, domain and scope of works. Therefore, by asking the people who manage and coordinate the Collaborative-CCA, we have better opportunities to understand the challenges during activity's performances. Through their perspectives, the research is able to get a richer, deeper understanding and fairer data about the activities since they have the whole perspective of the phenomenon and more experiences by observing and managing various ranges of the Collaborative-CCA phenomenon with less biases because they are describing other people and not themselves. From usability studies, Sauro (2012) emphasizes the importance of the secretariat as the surrogate users. The real users sometimes tell what they want and cover up certain things instead of telling what is really happening. Thus, by having the

surrogate users to answer the interview, the research can get a better description of the process of collaborative-CCA

c The Task and Setting

Following qualitative methods, data was collected using semi-structured interviews. Before the interview, there was a session to introduce the objectives of the interview and to briefly explain about the interview objectives and settings. The interview was divided into initial and main phases. The initial phase of the interview was to get a mutual understanding about the participants' background and how they relate and perceive the collaboration in CCA. First, the participants described their level of education and working experience. Then, from the working experience, the researcher will pick and discuss any of the Collaborative-CCA situations by including and explaining additional facts in the scenario. Finally, by building mutual understanding, indirectly the participants will gain a better understanding of the concept of the Collaborative-CCA that the study seeks to investigate. Furthermore, to identify the challenges during the process of CCA in the collaborative settings, the following tasks have been set up during the main phase:

- From the example of the scenario in building the mutual understanding above, the participants were asked to give a few examples of recurring problems during the activities. The interviewer then picked one of the problems by relating to the identified challenges found in the LR. All of the participants were giving the space to describe the problem clearly and explained fluently about each of the challenges.

- While they are describing that, the participant had been asked further on how to build an understanding for the situation and how to handle it if there are any issues.

- Then the process had been captured from the participant's verbal, participant's thinking aloud and picking points while describing their job scope.

- By seeing the difficulties of the participants to understand the point of the challenges, some of the challenges have been asked a few time by using different examples and scenario to make sure the participant is able to grab the question and provide the consistent answer.

d Data Collection and Management

The data collection must ensure to capture the data related to the Collaborative-CCA challenges. In order to do that, the research analysed the data from the audio recording for discussion among the users – that must be transcribed for each of the interview (Yin, 2010) as Table 3.4

Table 3.4 Data Collection Method for Semi Structured Interview

Data collection methods	**Type of data**	**Samples of data**	**Research instruments**
Discussion among the Participants	Verbal language Suggestion, ideas or arguments. Communication between the users while referring to visual representation	*"It is difficult for me to remember all, thus I draw the mindmap for self learning"*	Researcher as the main instrument Device Audio recording Transcription

e Deductive Qualitative Analysis

The analysis will be conducted based on the deductive qualitative analysis - DQA (Gilgun, 2011; Carbone, 2014). Through DQA, the thematic analysis process based on open coding will be carried out as usual, but analysis codes for a theme have been assigned based on the unit of data analysis as in table 3.8. According to Yin (2011a; 2011b), the unit of analysis selection is critical to understand how the evaluation might relate to any broader body of knowledge. The unit of analysis for this verification is then concentrated on the activities (sequencing in process) of how the users handle the challenges during the Collaborative-CCA as group dynamic topics. Along with activity consideration, the criteria for DQA verification are based on the findings from the LR.

To analyze the data, we first read and captured the relevant quotation from the script (please refer to appendix A for the example of the analysis work). The software of Atlas.ti version 7.2 is used to support the thematic analysis process. Each quotation will be grouped according to the similarities and the new subthemes will emerge from the group. Then the collection of subthemes should support the theme. Since the research is conducting DQA, we found the data from 10 participants from the combination of criterion and emergent sampling is suffient to replicate the study. The sufficiency can be seen after comparing the analysis findings based on the themes and unit of analysis that has been identified earlier. On account of secretariats, they gave quite a consistent and fair observation about the Collaborative-CCA phenomenon, especially from activities and process perspectives. Even though the participants were describing the situation in many layered, nuanced, details and a variety of examples, the data are leading to the similar theme. Thus, the research found the purposive on criterion sampling with addition to emergent sampling is helpful to suffice the data according to the study objectives. Moreover, the research is conducting DQA, so it is quite straightforward on the rigor and validity. As long as the data is capable to answer all of the criteria that have been identified from the LR, then the data is sufficient for the DQA.

3.5 ACTIVITY 2 - DEVELOP THE VISUAL REPRESENTATION DESIGN

Developing the visual representation design theory and its principles is the main activity for this research. The main intention for this phase is to create the solution that serves the identified problem. Thus, the outcomes from the previous activity 1 are pre-cursor in theory and theorising the solution for the visual representation design theory. Two DSRM phases are required to guide the development of the visual representation design theory: i) Define the objective of the solution and ii) Design and development. The details for each of the phases will be discussed in the following paragraph.

3.5.1 Define the Objective of the Solution

The objective of the solution will be define by reflecting the Collaborative-CCA challenges from the visualization perspectives. It is going to be done after knowing the

problem from the previous phase. Continuity from the previous phase, this section should answer what are the specific criteria that the solution for the problem defined should meet, what is the possible and feasible solution and how knowledge tools (methods, technologies and theories) are selected and applied to help with defining the objective of the solution. Therefore, in order to understand how the problem can be solve, the research reflected the challenges from visualization perspectives. The LR is also used to reflect the identified collaborative of the CCA challenges from the visualization design point of view.

3.5.2 Theorizing the Visual Representation Design.

This phase aim to create the visual representation design as the prime design artifact that is able to solve the identified problem. The important element from the DSRM point of view is the application of methods, technologies and theories to create an artifact that solves the problem. Thus, the visual representation design is an integrative element from the reflection of challenges, approaches and theories as to perform the solution in handling Collaborative-CCA challenges. This phase use the theories to theorizing an effective solution. According to Venable (2006), theory and theorising have long played an important role and being the central activity in defining the objective of the solution. Walls et. al (1992) state that theory and theorising will provide the feasible approach to handle the problem and the output of this activity is a tentative/meta design. During the theories application, we examined each of the challenges in relative isolation while still keeping their necessary relationship as an important aspect of in any complex situation.

3.6 ACTIVITY 3 - EVALUATE THE PROPOSED OF VISUAL REPRESENTATION DESIGN

To evaluate how well does the theory as the visual design solution work, this research use focus group observation to demonstrate and access the effectiveness using 3 different cases. During this activity, the research observed and identified how well the visual design theory is being the solution to resolve the problem by comparing the objectives with observed findings. The practical usefulness of evaluation is also

essential since the artifact is new in the explorative mode (Pfister & Eppler 2012). In order to do that, this objective needs guidance from the last two phases of DSRM which are demonstration and evaluation as describe below.

3.6.1 The Demonstration

The demonstration phase is important to gather the users' context use and then demonstrate the design theory into visual representation instrument that can be used during the evaluation later. According to Peffers et al (2006), demonstration is the process to demonstrate the use of the artifact to prove that the artifact works by solving one or more instances of the problems. The most important part during the demonstration is to explain on the 'how' knowledge to use the artifact to solve the problem and further describe how the applicable visual design is workable for users'. However, for this particular study, since the complex situation is context dependent, the demonstration only can take place after the sampling and criterion of the participants have been identified. Therefore by knowing which context to be investigate, then the demonstration can be customised accordingly.

Further than that, the demonstration is quite challenging since the research focused more about prescribing design theory and principles instead of desribing the design elements. Generally, according to Gregor & Jones (2007), design theory and principles are conceptual and at the higher level of abstraction since they are explaining why the theories or principles prescribed is neccessary to support collaborative-CCA while the visual representation instrument must be workable for the Collaborative-CCA usage in which is more on describing what the design elements are and how to implement them. Hence, from the ontological point of view, the design theory and principles can be translated and working from a diverse of the technological point of view. In this case, the research demonstrated the design theory and principles into visual representation instruments by putting some limits on the scope and utilising the previous tools and methods as described in the list of Table 3.5. However, the research does not limit this as the only way to demonstrate and apply the design theory. It can be diversified according to the developer's creativity and technological point of view. In this demonstration, we scoped down the CCA by

focusing only on a certain CCA type. Furthermore, the demonstration also utilised the prior visualization and other research works such as Knowledge Visualization Framework (KVF), Myer-Briggs Testing Indicatior (MBTI) (Gardner & Martinko, 1996) and visualization taxonomy to help during the demonstration and minimized the cost and time consumed on developing the mockup of the visual representation instrument conception on the paper based platform. The execution of the demonstration will be further explained in the next paragraph.

Table 3.5 The Limitation for the Demonstration

No of Limitation	**Description**
Limitation 1 – CCA Type	Since there are numerous type of CCA and each of it has more details and its own field of study, the research concentrated only on strategy planning as the CCA domain for this particular demonstration and evaluation. Since the strategy planning always involve multi division, roles and people in the organization, thus it is suitable for the collaborative case. Other than that, strategy planning is also related to other type of CCA like decision making, problem solving and sense making.
Limitation 2 – Identifying Individual cognitive type using MBTI	For identifying the personalization during the context of use, Myerr-Briggs Testing Indicator (MBTI) has been used to identify the user's cognitive type and personality that have been involved in the Collaboration. The use of MBTI is important during the process of understanding the users and their context of use to create a shared understanding.
Limitation 3 - Individual cognitive type for the awareness of different mental model	Individual cognitive type based on MBTI can be widely used to elaborate about personalization and behaviourism. It can help to let an individual get more understanding about their learning type, potential career and why they behave a certain way. However, for this particular demonstration, the research used MBTI results to bring awareness to the users about their different cognitive style. This will help to explain why they may face different opinions and thoughts during the collaborative-CCA process. By understanding their own and group members' cognitive styles, it might help to lose some tense and bring more understanding about him/herself and also their peers during the constructive arguments.
Limitation 4 – The selection of visual structure - periodic table of the visualization menthods	The visualization field has developed various taxonomy, classification and aggregation . Most of them are based on task, data type and function (Tory & Moller, 2004). Based on the strategy planning as the CCA domain, this demonstration is referring to a periodic table of visualization methods as the classification for the management tasks in the organization (Lengler & Eppler, 2007). Thus, the selection of the visual structure will be focused only from this table.
Limitation 5 – Paper based prototyping	Paper-based mockup is well known and widely used in a user-centered design process. This method of prototyping enables the visual representation design to be the visual representation instrument. It is simple, cost-saving and practical to be used. Another benefit of paper based prototyping is being more flexible and free-and-easy to use since the users can see, write, draw, delete and add information on the visual structure based on their needs during the evaluation. More over, it is capable to cater the needs of perceived finishednes and modifiability on the visual structure and allow the dynamic interactivity that is seldom and expensive to have due to current market technologies.

3.6.2 The Evaluation

Based from the activity central point of view, the evaluation should be able to observe how the visualization representation space is able to facilitate the Collaborative-CCA process. By taking into account the necessity of sampling and research method based on the activities and processes, the focus group observation is chosen as the method to evaluate the visual representation design. Using this method, this research was able to observe the interactive collective process while the participants performed CCA face-to-face in a collaborative setting (e.g., meetings, discussions, and workgroups). The method is selected to balance between the values of freedom of qualitative methods and the control environment for the deductive process. This is because, the investigation of complex phenomena especially when dealing with the activities is not a straightforward process (Tong et al. 2007). Even though the visual representation design (VRD) is essential for evaluation criteria, the natural settings for activities are also important. Thus, we embed the qualitative component by observing the activities in a real setting for this study.

The evaluation can only take place when the visual representation instrument as the outcomes from the demonstration is completed. It will act as the control environment during the evaluation process. During the focus group observation, we only provided two main elements for the evaluation. The first is the goal of the complex cognitive activities to be performed as a group, and it was based on our early agreement with the participants during the understanding for the context of use. The second was the visual representation instrument that had been derived from the VRD demonstration to facilitate the participants. The focus group observation lasted around 90-120 minutes, and during that time, the participants in the group of 4-6 people were gathered in the meeting room. Based on the goal, the groups were to discuss as in a normal meeting or discussion group as long as they would refer and utilize the provided visual representation. Then we observed and recorded the collaborative process as an evidence on how the visual representation instrument would be able to facilitate the process of Collaborative-CCA.

Based on LR, this research also faced the difficulties and uncertainties on designing the evaluation since the guidelines for a complex condition has already mentioned about the context dependent and natural condition as mentioned by Albers (2010), Redish (2010) and Lam et al (2011). Furthermore, the evaluation for activity-based is seldom to find since the visualization field is having more on the evaluation for user-based. Thus, we derived on the evaluation guidelines after going through an iterative process as described below.

3.6.3 The Improvements for the Evaluation Guidelines.

The iterative of the evaluation process has helped us to improve the evaluation guidelines, especially from the perspective of sampling criterion, task and settings. The research found the improvements are very beneficial for more practical usefulness value based on the activities natural settings. Based from the design cycle (Hevner, 2007), the iteration between the design theories (the proposed VRD) and evaluation guidelines were based from three levels: (i) follow the evaluation guidelines from LR, (ii) participate in the more natural settings study and (iii) provide the settings based on users need and situations. The refinement and accessment of these cycles will be explained in the next paragraph.

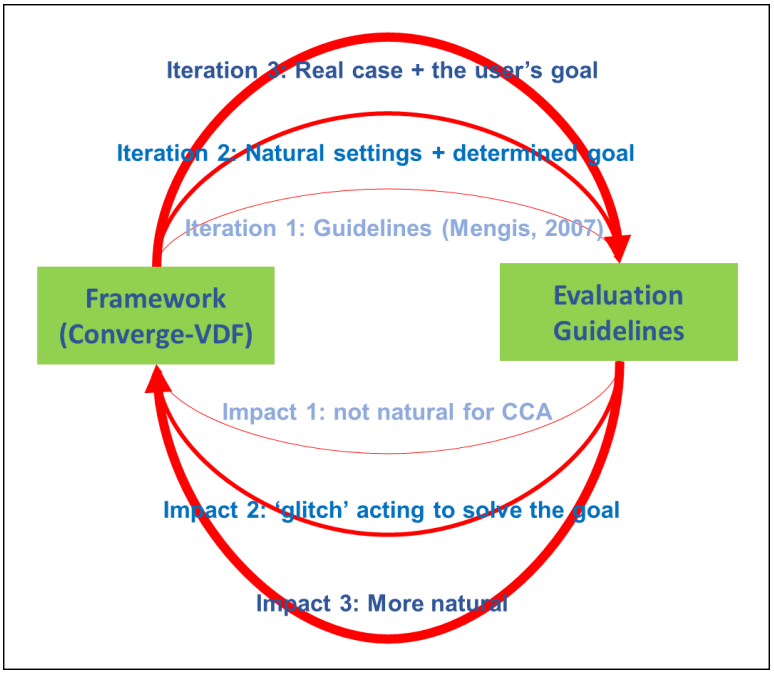


Figure 3.3 The Iteration of Design Cycle

First iteration, the research followed Mengis (2007a; 2007b) and Dickie (2000) in order to achieve the similar natural setting goals for evaluation guidelines by performing experimental class by applying case study. In Mengis' case, she selected the participants among the students and determined the topic for their discussion. However, we found the determined topic and participants for the case study were not suitable for the complex domain. In CCA, the participant's cognitive background plays an important role to digest and execute the activities. By taking students as the participants, we found their blurriness in digesting the complex problem. They seemed to be awkward to remember and think based on their roles and most probably, the roles given are not suitable according to their level of thinking, knowledge and personality. Other than that, the participants were having a hard time to discuss about the topic since they didn't have well experience according to the organization settings (e.g. decision makers roles, sales manager roles or secretariat) and domain problem (e.g sales for shipping company, food and franchising modus operandi and Vendor as IT Integrator)

Second iteration, to improve the participants and topic selection, the evaluation is the collaboration settings (e.g meetings, discussion and group work's assignment) from the different backgrounds of the participants. Then, the elements like the selection of group members, what to achieve and the CCA topic of discussion have been identified and well-documented in graphic charts, reports and persona storytelling. The document must be given to the participants three days before the experiment takes place. However, we still found some glitches to mock up this kind of evaluation. The participants were awkward among each other because they didn't have a bonding and the topics sound unfamiliar to certain participants. Other than that, the elements of acting and the staggered information and idea flows make the discussion seemed not natural at all.

Third iteration, we improved the settings by lessening the determined control settings and provided the settings based on the users' goal and condition. We selected the participants from the group which they already have their bonding – which meant we must take the group from one organization/company. It was easier because each people in the group already have the same vision to achieve and understand their own

roles and what to expect from others. Within that, we eliminated the awkwardness among the users since they have natural bonding. In spite of the mocked up and determined topic and CCA for them, the research got a deeper understanding about their needs and the Collaborative-CCA to be performed and let the experiments be the platform to solve their own CCA's problem. After having the success for the first group on executing this kind of evaluation, the research gained confidence and executed the same process for two other groups. Therefore, the evaluation has change from determined and strict control environment of experimental class by applying case study into more natural settings and activity of focus group observation. The evaluation guidelines that will be described below are based on these final improvements.

a The Unit of Analysis and Criteria for the Evaluation Assessment.

Along with the collaborative consideration, the unit of analysis for the evaluation is the interactivity between users and visual representation. In spite of evaluating the usability that weight more on instruments's ease of use, the research focused on the usefulness to higlight the instrument's quality of being useful (Norman, 2013). Thus, in this research, the interactivity will be observe through an interactive collective analytical process. Based on this unit of analysis, the criteria for the evaluation is based from the reflection of the VRD roles and Collaborative-CCA challenges as presented in Table 3.6.

Table 3.6 The Criteria, Sub-Criteria and Unit of Analysis for the Evaluation

Criteria	Elements of the criteria	Unit of analysis
Criteria 1: Capabilities to centralize the Collaborative-CCA guidelines	- Centralized mental model - Clarities on how knowledge can be formed	Interactive collective analytical process
Criteria 2: Capabilities to facilitate the convergence.	- Show clarity about the main drivers - Can observe and draw the interconnection between various elements	Interactive collective analytical process
Criteria 3: Capabilities to handle the emergent patterns	- Contextual guidelines for knowledge Construction. - Extent mental model for constructive Content	Interactive collective analytical process

Based on the need to understand the interactivity process, the researcher will observe the focus group throughout the Collaborative-CCA process (Liu et al 2008; Isenberg et al 2011). The method requires that events must be in natural settings to perform better within the real context. Thus, the qualitative method is the most relevant one (Yin, 2010; Yin, 2011a; Creswell, 2009). However, since we are evaluating the VRD, the evaluation must be able to access the VRD capabilities to play the intention roles. Then, the evaluation analysis will be carry out deductively by using deductive qualitative analysis (DQA) (Gilgun, 2010; 2011). By having deductive approach, the evaluation will become more specific and focus on accessing the usefulness of Converge-VRD design principles based on these criteria. By following Hevner's (2007) suggestion, in order to access the utility (effectiveness) of the VRD to handle and facilitate the collaborative-CCA process. Therefore, each of the criteria is the reflection from the challenges identified in chapter 4 and it must be able to play the representation roles.

b The Sampling Strategy and Participation

Based on the purposeful sampling strategy and collaborative-CCA activity-based, the research chose the management team that intended to perform strategy planning from the organization as the participants. Three (3) groups of users were selected from different organization from the public and private sectors in Malaysia. The focus groups for the observation are mentioned in the Table 3.7.

Table 3.7 The Selection of the Participants for the Evaluation

Group	Goal to achieve	Subject Domain
Group 1 (4 participants)	Product Development Strategy	Agriculture investment for 18 acres of land in Nilai, Negeri Sembilan
Group 2 (5 participants)	Business Developement strategy	Business investment on 2500 square feet of land at Kuala Lumpur
Group 3 (5 participants)	Inclusiveness and ownership Strategy for Public Sector Transfromation Programme	Collaborative decision strategy for public sector professionalism (Public Sector Department)

As this research is designed to investigate the effectiveness and value of the VRD for facilitating the Collaborative-CCA process, the research used a purposeful

sampling strategy (Patton, 1990) to select the participants based on activities they perform. Furthermore, the evaluation is focusing on activity centric, thus, the sampling must come from the Collaborative-CCA activity-based and real settings. As a result, less restriction had been put on the participants' individual criteria since the focus group observation needed to be more flexible and adapting the real case necessities (Dickie, 2000). By applying the case study, the research intend to observe the interactivity process in a natural way. Thus, there is less strict criteria on participants' since the evaluation is an activity and case study basis, the focus group observation seems to be more flexible and open-ended to adapt the real case necessities.

c The tasks and settings.

Since the evaluation main concern is to observe how the visual representation design will effect the Collaborative-CCA process, the visual representation design must act as the control environment (instrument) for activities' facilitation. The design of this study does not limit the freedom of participants to act, think, draw and express their views during the Collaborative-CCA process. From the focus group we would like to observe the feedback loops between participants and the visual representation instrument. Basically the tasks and settings for focus group observation is divided into three divisions: before, during and after the observation. Before the observation, the consent form has been given to each of the participants in the group (as an example in Appendix B), after getting the permission, then the research start to demonstrate the VRD into the visual representation instrument that is to be used during the focus group activity. During the observation, the usefulness of the instruments will be demonstrated and evaluated. Then, after the observation is the process to manage and analyze the evaluation data to develop valuable findings.

Before the focus group observation is the demonstration of the VRD into the visual representation instrument. This process will turn each of the principles for the VRD that has been developed into the workable instrument. Due to the complex condition that is context dependent, the demonstration can only take place after the participants have been identified, then the activity to understand the activity's context

of use and group fit design will be according to the selective participants. During the observation, the usefulness of the instruments will be demonstrated and evaluated. Based on our early agreement with the participants while understanding the context of use, the focus group aimed to perform and solve the CCA goal. The activity lasted around 90-120 minutes, and during that time, the participants in the group of 4-5 people were gathered in the meeting room. The groups were to discuss as in a normal meeting or discussion group as long as they would refer and utilize the provided visual representations instruments. Then we observed and recorded the interactivity as an evidence on how the visual structure would be useful to facilitate the Collaborative-CCA process. After the observation, the researcher has discussion with the group to clarify certain findings from the observation and give some time for them to express their view about the activity, instruments and the topic of discussion.

d Data Collection and Management

As noted earlier, the main goal for the evaluation is to see how the VRD is being useful to facilitate the participants in handling the complexities in the collaboration while performing CCA. In order to capture how the visual representation is used, the research used three types of data-capturing devices so that we would be able to triangulate the analysis process: (1) audio recording of the discussions among the users, (2) video recording to capture the human interactions not easily recorded using audio; and (3) annotation in the visual representation application (Yin, 2011). A summary is provided in Table 3.8.

Table 3.8 Data Collection Methods

Data collection methods	**Type of data**	**Samples of data**
Audio recordings for the discussions	Verbal language, suggestion, ideas or arguments and communication between the users while referring to visual representation	*"I can see the interconnection clearly"*
Video recordings	Physical actions and gestures during communication among the users and visual representation Physical actions and gestures while communicating between the users by referring to visual representation *(body language – posture, gesture, facial expression, eye movements)*	The users pointing to the visual representation Clarification of the expressions Users writing the input, sketches or links within the visual representation
Content records in the visual representation instruments	Sketching Writing text, important points and symbols on the visual structure	Drawings lines or symbols between two parts Writing something onto the visual representation

e Deductive Qualitative Analysis

Thematic analysis was carried out after the transcription for the three cases. The analysis was conducted based on the deductive qualitative analysis – DQA. The thematic analysis process based on open coding was carried out as usual (please refer to Appendix C as the example of transcription and analysis work based on three types of data collection methods), but the codes for a theme had been assigned according to the criteria and unit of data analysis. We first transcribed the relevant verbal expressions into quotations. Each quotation would then be grouped according to similarities, after which themes/subthemes would emerge. Since we are evaluating the visual structure, triangulation was essential to complement each of the quotations with video observations and content records in the visual structure that were related. To avoid misleading interpretation, the researcher also made the peer-review session to check the themes and findings interpretation. During that session, the peers reviewed the quotation, video observation and content records in the visual structure. Then the peers agreed, disagreed or gave an opinion for each of the identified interpretation for each of the sub themes. After the peer review session, the result and findings from the evaluation were finally discussed appropriately.

3.7 RESEARCH OUTCOMES AND THE CONTRIBUTIONS

After finishing all of the research process, the research findings need to be communicated in order to understand how well it contributes to the body of knowledge and the users. Generally, this research is rooted from the visualization field that applied DSRM for having an effective visual representation design for the Collaborative-CCA process. That means, the research must be able to present and communicate the outcomes from the DSRM perspectives, then from here – it will explain how the DSRM outcomes will bring benefit to the visualization field and it's users. After drafting the outcomes, the reseach will communicate (please refer to Appendix D as the invitation letter for the expert review) the process and the outcomes by having the review and discussion with the experts from the DSRM and visualization field based on their biography as mentioned in Table 3.9. Therefore, the final outcomes, contributions and limitations after the experts' review will be discussed in Chapter 7.

Table 3.9 Experts' Details

Expert field	Designation and expertise
DSRM – Design Process Perspective	Senior Lecturer, Universiti Teknologi Malaysia He is an experienced lecturer of Information Science (IS) related discipline. His research domain is more on Ontology and Metamodeling especially for special interest group. Furthermore he is well experience in applying Design Science Research Methodology (DSRM) as the research methodology for the IS works and applications, in which the research found his ability to give the constructive feedback about the contribution from design process and DSRM perspectives.
Visualization Field – Collaborative-CCA Perspective.	Associate Professor, Senior Lecturer, Universiti Teknologi Mara. She is in the field of Human Computer Interaction (HCI) related research. Particularly has interest in information visualization (IV) fielad and personalization. Since her focus is on the user-centered design and evaluation of artifacts that concerns with users' perceptual and cognitive abilities and limitations, the research found the relevancy of her expertise to review this research contributions.

3.8 CONCLUSION

The suitable methodology has been the challenge for this research. Based on research philosophy, mode and direction for Collaborative-CCA, the visualization design is more on epistemological, conception and theory building. Thus, the current visual design process is inadequate to properly guide this kind of research values. Instead of centralizing and involving only the users during the analysis, design, development and deployment phase, this research focused more on the rationales and activities for the Collaborative-CCA phenomenon. The research must go beyond the users and dig more about their context of use and the activities involved and from here the research should be able to prescribe the solution. Furthermore, the solution must be returned and evaluated in the collaborative-CCA context of use to justify the relevancy. One of the advantages of using DSRM is the flexibility for the phases to be combined with other appropriate methods. The encouragement to adapt others theories and methods is what is needed most since the Collaborative-CCA domain is new and we needed the research from other fields to help us. Therefore, the expansion of DSRM is capable to guide the research on these conditions.

Chapter III is being essential for this thesis. It is not only meant to govern the research design, moreover, combining DSRM with other appropriate methods will extend and refine the guidelines as the rightful methodology. Through the credible and clear guidelines, the research process will be more systematic and the outcomes can be more rigor, relevant and trusted. Furthermore, the research has the strong foundation to justify the novelty contributions to the visualization as a body of knowledge and its users. The rest of the chapters will follow the phases and steps for the design guidelines and come out with the outcomes for the research.

CHAPTER IV

THE COLLABORATIVE-CCA CHALLENGES

4.1 INTRODUCTION

Due to develop an effective visual design for Collaborative-CCA, the vision for this chapter is to mutually understand why the activity of collaborative-CCA needs the visual facilitation in Collaborative-CCA. By the end of this chapter, the thesis will provide an explaination for a set of challenges faced during the collaborative-CCA process as a rationale to support the development of visual design later.

Being a pragmatist, this research is a problem centered that focused on real world practice and consequences of actions (Creswell, 2009). Further than that, by following DSRM (Peffers, 2007), the thesis states the concern for the solution design to the problem and then shall arises out actions from the problem situation. Instead of focusing directly to the problem in the visualization field, this research emphasized the problem first and later found a way by using any of the approaches availabe to solve it. Therefore, by alligning with Creswell (2009) and March & Smith (1995), this research conveyed the importance in focusing attention to understand why the Collaborative-CCA phenomenon has become a challenge to be facilitated. Since the research in the Collaborative-CCA is still a new area to explore in the visualization field, the research needed to identify the challenges from scratch. To enhance the credibility of the identified challenges using human-activity centric approach, this chapter will further investigate the challenges from two conditions:

- Understanding the Collaborative-CCA situation from LR. The LR is basically derived from researches about organization, collaboration, management, complex system, business analytics and visualization

- Validating the challenges found from LR in the real case environment. The verification for the challenges are based on deductive qualitative analysis (DQA) for semi structured interview with 10 participants from real organizations.

Furthermore, these two conditions have been the main steps during the research design process as summarized in Figure 4.1. By relying on the foundations and methodologies from the knowledge base as stated in the figure, this chapter aim to identify a set of the collaborative-CCA challenges as an outcomes from this research design process.

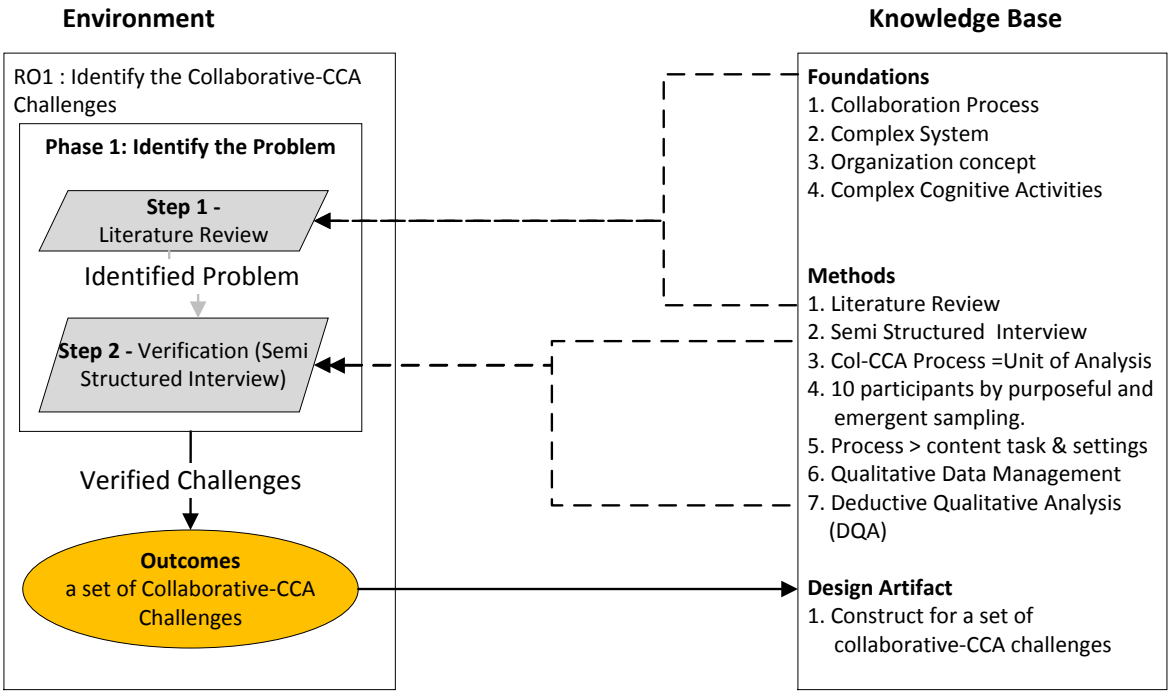


Figure 4.1 The research design process to identify the Collaborative-CCA Challenges.

This chapter is presented according to the above components. Section 4.2 and describe more about the working background of collaboration and CCA mainly from

the perspective of context and activity-process. Eventhough the research had better understanding on what, who, where, when and how collaborative-CCA has been challenge from visualization perspectives, this chapter intend to dig further about the why question especially from collaborative perspectives while performing CCA in the real organization settings. Then Section 4.4 describes the findings from the LR, by using the set of challenges identified in Chapter 2 as a basis. In this section, the research will further describe, develop an understanding and appoint the difficulties during the previous LR as a set of challenges for Collaborative-CCA. Then, in section 4.5, we then expand the challenges by table out the findings from verification and enrichment of the DQA between the previous LR findings with the real organization settings. Section 4.6 provides a discussion about a descriptive set of Collaborative-CCA challenges from the whole perspectives identified during this activity and finally, section 4.7 provides a summary.

4.2 WORKING BACKGROUND FOR COLLABORATIVE-CCA.

The previous LR found the lack of understanding about the root cause of Collaborative-CCA problem in 'why' perspective. Even though, some research has emphasized the problem of increased complexities due to the complex matter and multiple participants, yet there is still a lack of understanding especially from perspectives of collaborative settings during the CCA process (Dillenbourg & Betrancourt, 2006). Therefore, this chapter intend to further investigate these conjunction challenges to have a better design decision rationales as to facilitate and manage the Collaborative-CCA process. Since the conception and challenges are clearer from CCA perspectives and the early stage of collaborative-visualization research is in inadequate for us to understand the overall concept of the collaboration, therefore, this chapter will further develop an understanding about it and the intersection challenges between the Collaboration and CCA.

Since the research has focused on the organization as the visualization design user and its context of use, then the phenomenon of collaboration between the people in the organization while performing CCA will be further understood and observed. The collaboration has been define as *''a recursive process where two or more people*

or organization work together to realize shared goals. For example, an intriguing endeavor that is creative in nature, by sharing knowledge, learning and building consensus. Teams that work collaboratively can obtain greater resources, recognition and reward when facing competition for finite resources" (Briggs et al, 2009). Example of the Collaborative-CCA in the organization is like a management meeting, group discussion and peers' conversation according to the complex job.

Due to the aim of the visual design to support the process of Collaborative-CCA, two elements are essential to understand: context and process. To understand the first element, context - it is important to understand the background of the Collaborative-CCA to get the view on what is going on (Briggs et al. 2009). Moreover, it is important to describe the collaborative task, knowledge content and task context in order to have a meaningful, rightfully and able to achieve the collaboration goal. Process is the second element which can help us to understand the Collaborative-CCA activities and tasks. Through it, we understand why certain processes need to be support and how is the best way to facilitate them (Jonassen 2008). The thesis briefly review these two components from the literature and present in the next paragraph.

4.2.1 Collaborative Background from Context Perspectives.

Organization is an organized body of people with different tasks and roles with a shared purposed. It always takes place for a business, society and association. According to Maisura (2004), the achievement of an organization depends on two elements; human and non-human. The human element comprises of leadership, expertise and communication while non-human element comprises of technology, process, policies and equipment. To ensure the success of an organization, human and non-human elements need to complement each other and work as a team. The vision and the outcomes of an organization are closely related to the human elements. As an example, a decision maker and an expert as the human elements play an important role to make a decision in the organization. In recent years, we observed a general trend in organization toward increasingly complex and dynamic condition, thus it is

essential for human elements to have the capabilities to handle CCA, response and act accordingly to stay relevant in the market.

Here, non-human elements such as facts, procedures, documentation and presentation have been playing an important role to facilitate and support the human elements in the organization. During the decision making process, especially when it comes to CCA, visual design via presentation (e.g Power Point, Excel and Prezi), dashboard (e.g Knowledge Management, Business Intelligent and currently Big Data) and simple visual graphic and charts have been generally useful to ease the cognitive process for the human elements in the organization (Elias & Bezerianos, 2011, 2012; Elias, 2012). However, when it comes to a collaborative situation, the interactivity between multiple human and non-human elements have increased the complexities during the CCA. The increasing of the complexities due to the collaborative phenomenon is because:

- From an organization point of view, the consideration to communicate the knowledge during Collaborative-CCA process is important. In general, organization consists of various parts of departments, units or divisions. Each part will be classified to form a focused, skilled expertise in a certain field. Thus, the management defines the roles, tasks, functions, responsibility and authority of each part in carrying the organization's main vision. During the collaboration, each of the part and the individual will interact and affect each other and how well all these parts can cooperate as a team will determine the organization's efficiency and reliability. For example, in the department that manages the financial, the main division has been established as taxation, budgeting and accounting led by experts associated with the field. Regardless of the parts, when performing CCA, experts from each of the division should be consulted to get insights, information and relationship areas of expertise with the system of interest that are being faced. This kind of practice has become a norm in today's organizations. Therefore, the ability on how well a collaboration takes place becomes a major factor in shaping the better quality decision for the CCA.

- From the cognitive point of view, the consideration about reasoning and knowledge creation during the Collaborative-CCA process is important. According to Bartlet (2001), the consequences of the reductionism approach has made an organization develop the decision based on analytical thinking alone. It is difficult for them to understand the interconnection between different divisions (synthetical thinking) to develop a comprehensive whole decision during the CCA process. Based on Figure 4.2 below, synthetical thinking has been ignored since the focus is more on the analytical which each of the division or elements have been analysing separately and the decision is based on the whole as sum of it parts. As an example for problem solving CCA, the organization is capable of diverging during the brainstorming and coming out with the great option of solution. When it comes to the decision phase, the convergence of the reliable ideas to become one whole integrative solution is lacking to happen. Usually, the organization will pick the best solution. Due to the assumption of the whole is sum of its parts, there is less consideration to synthesize different opinions to become one integrative solution.

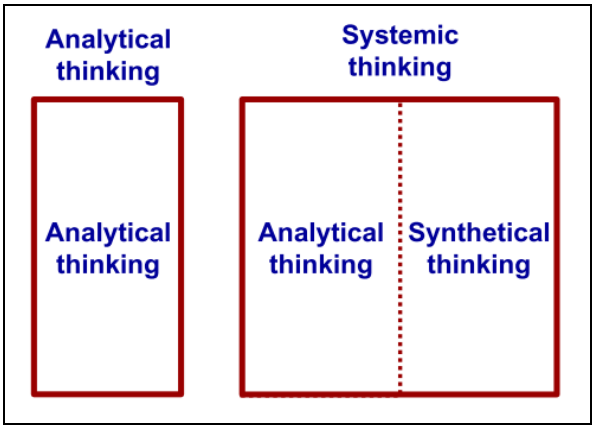


Figure 4.2: The Lack of Synthetical Thinking in the Organization During the Collaborative-CCA Process (Source: Bartlet 2001)

4.2.2 Collaborative Background from Process Perspectives

In reviewing the collaborative challenge literature through the lenses of process, we have identified four prominent and well documented collaborative processes worth exploring more deeply: The process of convergence in the collaboration (Kalfshoten

& Brazier, 2012), a process model of knowledge communication (Eppler, 2012), design thinking process (Liedtka & Ogilvie, 2011) and Organization Learning (Senge, 1990). The selection of these four collaborative processes are based on the context of collaboration. Even though some of them are not specifically mentioned in the collaboration, but the context and purpose are for collaborative benefit and show concern in CCA. The next session has a brief review about all descriptions for the challenges consequences. Table 4.1 summarizes these:

Table 4.1 The Summary of Process Model that Related to Collaboration Context

Phases of the Process Model Commonalities	**Kalfschoten & Brazier (2012**	**Eppler (2012)**	**Liedtka (2011)**	**Senge (1990)**
Problem identification	Identify problem	Expert Introduction/ Need articulation	What 'is'	Personel mastery
Divergence	Divergence	Analysis	What 'if'	Mental model
Convergence	Convergence	Transfer of result	What 'wow'	Build shared vision
Applying on decision	Decision making	Application	What'works'	Team learning

Based on the table above, we can see that when a group collaborate, it often goes through the CCA with roughly four phases: i) Problem identification, ii) Divergence, iii) Convergence and iv) Applying on decision. Problem identification is the stage to explore current reality. It is an accurate assessment to identify the real problem and constraints and then decide what goal or aim to achieve. Then according to the goal, the group will diverge and converge for finally having a solution for decision making. Due to the cognitive and communication perspective, Wayne (2012) emphasizes two core phases during the collaborative-cognitive which are divergence and convergence (please refer to Figure 4.3). Divergence is the ability to think outwards and bring up unique ideas to problem thinking. Meanwhile, convergence is the ability to bring facts together and then apply the knowledge and logic of it to the problem as the solution. Both are important and complement each other in performing the Collaborative-CCA process.

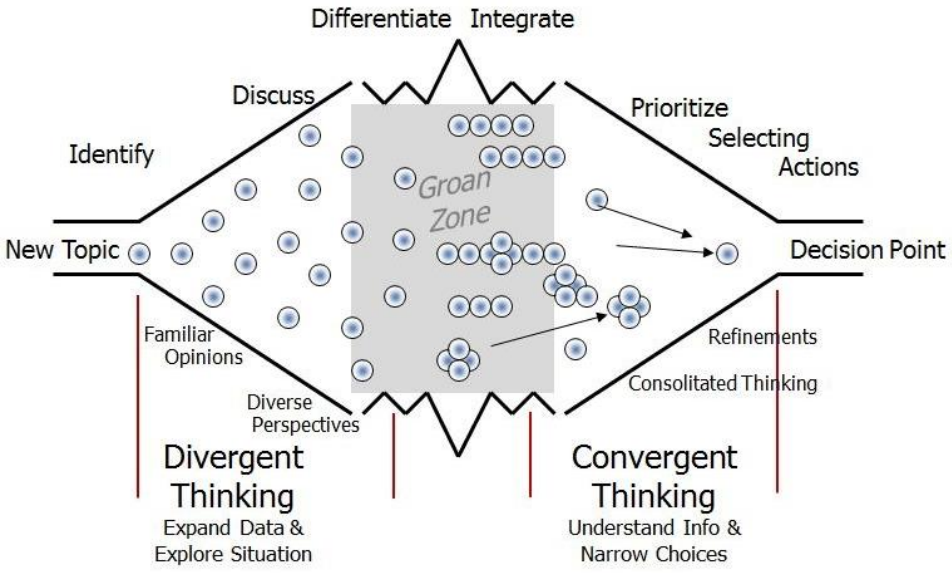


Figure 4.3 The Concept of Divergence and Convergence
(source: Wayne, 2012)

a Divergence Phase

Divergence is an ideation stage to envision a new future (Liedtka & Ogilvie, 2011). During this phase, the collaboration needs to consider new possibilities, trends and uncertainties in order to tackle the problem. The divergence phase is a fuzzy front end that has many divergent paths to explore and the goal of exploration is to identify opportunities that result in ideation, options or suggestions in order to achieve the main drivers. Often in cognitive-collaboration, divergence in general is known as the analysis (complexity learning, 2015). From the modern science perspective, divergence has been tackled from reductionism approach where divergence will break the system into elementary components, then each of the components can be analysed in isolation before re-combining all the components back into the original system that can be described from individual elements. Since the concern within divergence is more on the variation of parts, then it has less concern in interconnectivity, interdependency and the relationship between the elementary components.

In the divergence phase, nominal group techniques and varieties of visualization tools have been used to support the divergence part. As an example, Liedtka & Ogilvie (2011) have identified the tools for brainstorming and concept development to identify possibilities. Mengis (2007a, 2007b), Bresciani (2011) and Eppler (2014) have continually enhance the 'Lets Focus' visualization software and Kalfschoten and the group (2009; 2011, 2012) used the 'Lean Startup' software for the same purpose. In the visualization-computer supported domain like data visualization, information visualization and visual analytics, the tools, methods and techniques that have been developed mostly cater the divergence phase which is known as the analysis phase. In short, many visualization elements in both the process and toolkit are visible elsewhere in divergence theory and practice. Thus, it would be hard to argue that visualization can offer a new or distinctive concept for divergence

b Convergence Phase

In contrast, the convergence phase is concerned in bringing together facts and applying logic and knowledge to the problem or situation as the solution. From the cognitive-collaborative perspective, convergence is known as synthesis which is primarily defined by the relationship of the elements in the system. Thus, the synthesis is the combination of components or elements to form a connected whole and is known as the 'holism' approach. According to Kalfschoten & Brazier (2012), convergence is a very complex collaboration task. It has been less studied than the often preceding, divergence. This is because, convergence is the process of relating and organizing the information shared in a group. Divergence often produce a large volume of content of varying relevance, across multiple levels of abstraction and of varying granularity. This knowledge, shared and created by a group need to be converge to a manageable size and to be used for further synthesis, evaluation or decision (please refer to the Figure 4.3)

The goal of convergence is to create a parsimonious overview of alternatives. Some judgement or evaluation is likely to happen. Alternatives could be removed whereas similar alternative can be merged and strategic behaviour can occur in this process. Thus, convergence can give rise to new ideas and consequently causing

ideation and divergence. In the collaborative settings, the convergence phase has been caused extra cognitive load and increased complexity because:

- It can originate from the information shared among participants through various communication channels.
- The process from constructing and thinking up new information.
- Explaining or arguing positions.
- Assessing value, implications and effects of decisions.
- Various procedures.
- Distractions.

Since the degree of complexities has been increased due to the convergence phase and it has been less supported, the users have been in a difficult endeavour. This research found the importance to highlight the convergence as one of the challenge during Collaborative-CCA. Research from Kalfschoten & Brazier (2012) and Vreede et al (2009) gave a deeper understanding on how convergence works. 6 sub-process and 42 cognitive activities have been identified during the convergence phase as shown in Table 4.2. The sub-process of Convergence has total 12 distribution of cognitive activities (from activity 19 – activity 29). It has been highlighted as the most burden cognitive process among 6 sub process of collaboration process.

In short, the convergence phase is crucial as the capabilities to synthesize, match the solution and achieve the desired goal of CCA is depend on it. Even though, the creative and good options have been identified during the divergence phase, without proper synthesis, match and connect to the prior problem, the quality of decision is more or less the same as an individual decision. Which means, the outcomes from this kind of situation is considered not achieving the collaboration goal as the collaboration decision is not improving the individual decision.

Table 4.2 Distribution of 42 Cognitive Activities within 6 sub-Processes of Convergence Phase (source: Kalfschoten & Brazier 2012)

Preparation	**Analysis**	**Convergence**	**Reflection**	**overall reflection**	**Distraction**
1 receive (listen, read) the convergence task	7 store contributions in memory to consider set of contributions	18 mark contribution for inclusion in converged list	30 consider implications of discarding contribution	35 reflect on size of converged list	40 identify new contribution
2 understanding the convergence task	8 consider the contribution to fit the scope	19 merge similar contributions	31 consider implications of class choice	36 reflect on inclusion of perspective in converged list	41 personal distraction
3 listening to the tools' explanation	9 consider set of contributions to identify similarity	20 rephrase similar contribution to articulate uniqueness	32 consider implications of creating relation	37 reflect on completeness of converged list	42 external distraction
4 study/observe/try out the tool & method	10 consider set of contributions to identify relation	21 label relation of contributions	33 consider implications of clarification/rephrasing	38 reflect on consistency of converged list	
5 understanding the convergence tool & method	11 consider contribution to verify clarity	22 label abstraction of contribution(s) as class	34 consider implications of converged set selection	39 reflect on quality of converge list	
6 transition from understanding to performing.	12 consider contribution to verify fit to class	23 visualize relation between contributions			
	13 to assess importance to personal stakes	24 resolve inconsistency in relation			
	14 mark contribution that is out of task scope	25 phrase summarized contribution			
	15 mark inconsistently related contribution	26 rephrase unclear contribution			
	16 mark unclear contribution	27 explain contribution to the group			
	17 mark similar contributions	28 rephrase out of scope contribution to fit scope			
		29 discard out of scope contribution			

The thesis also wants to highlight on the involvement of other phases (divergence, decision making) during the convergence. Even though the convergence is having their own high cognitive load, the complexities are increasing because the convergence phase is related and connected to other phases. The iteration between divergence and convergence is significant in handling the emergence information. Kalfschoten & Brazier (2012) notice that some cognitive activities involve the divergence phase in conceiving new ideas and the decision making phase in reflecting on implications of ideas. The relationship and involvement with other phases let the experts identified the task of overview and shared understanding with the highest percentages of overall cognitive load (58%) compared to the load of process (22%), reduction (14%) and ineffectiveness (6%). Moreover, in the collaborative settings, the emergence of information is essential in bringing new input and output throughout the complex activities process and then the interdependency between the convergence with other phases are iteratively active during the Collaborative-CCA process.

4.3 LITERATURE ANALYSIS FOR COLLABORATIVE-CCA CHALLENGES

After getting a deeper understanding about the collaboration background in this chapter, the research found a slightly different challenges for the intersection of Collaborative-CCA compared to CCA alone. Eventhough, there are continuity and relevancy from the previous LR findings into these intersection of Collaborative-CCA challenges (mentioned for complex condition in section 2.2.2 [what] and complex cognitive activities in section 2.6.1[why]) as shown in Table 4.3, the challenges become more critical since it involves a distinguished background of the multiple partcipants that increase the cognitive processes towards achieving the same goal. Furthermore, the collaboration required the cognitive to perform more than the analysis, hence it involves the synthesis during the convergence phase. Finally, the collaboration involve the evolvement of input and output during the CCA process that lead into knowledge construction. Each of the paragraph below will explain these intersection challenges in more details.

Table 4.3 The Continuation and Relevency for the foundation of Collaborative-CCA Challenges from previous LR

No	The challenge of complex system *(Section 2.2.2)*	The challenges of CCA *(Section 2.6.1)*	The intersection challenges of Collaborative-CCA
1.	**Ensemble of many elements**	**Ensemble of many cognitive processes** Many of cognitive processess occur from higher level of cognitive (e.g analyze, synthesize, evaluate and create) that emerge from availability of information.	**Context of use and group-fit necessity** Distinguished background of users lead to different mental model during the Collaborative-CCA process. (a). Different roles (b). Different level of knowledge (c). Different social background
2.	**Emergence**	**The Construction of New Knowledge as the CCA emergence** Emergence of knowledge from interconnection between information elements from multiple sources, level of depth and abstraction and relevancy to the goal of CCA	**The lack of understanding and supporting the Convergence** (a) Understanding the main driver i. No centralized guidelines ii. Difficulties to appreciate value of collaborative main drivers iii. Difficulties to sustain the main driver direction. (b) Understanding the interconnection between elements in different level of abstraction and details
3.	**Evolution**	**The Evolvement during the process of knowledge construction** The dynamic and evolving of cognitive process incur the cognitive overload over the time.	**The evolvement during the process of collective knowledge construction.** (a) The evolvement of collective input for the cognitive process (b) The evolvement of collective output from the cognitive process

4.3.1 Context of Use and Group Fit Necessity

The CCA is dependent on the context of use. Since it happens in the collaborative settings, then it also must be a group-fit design. From the organization perspective, we found the essential of CCA to perform in the collaborative setting. Since it often involves higher level thinking, the CCA process requires views from experts who come from different areas within the enterprise, with different expertise and are familiar with their own ways of data representation – which is the CCA performing in a group and the group members being very context dependent (Heer & Agrawala, 2008). In this collaborative situation, the four types of cognitive biases (self-serving biased, cognitive fluency, sunk cost fallacy and confirmation biased) will become more dense and cloud the judgement since each of the users has their own cognitive

bias (Liedtka, 2014). This will lead to the conflict when each of the users relies on their mental model and bases on their own cognitive biased. Therefore, it is essential to address the need to communicate the analytical results that meet the group fit neccessity. In the Collaborative-CCA settings, the research has identified the needs to understand the context of use especially for a group-fit as it is essential. The concern on the context must be customised as the group-fit since the collaboration must handle the variety of users' functions, roles, knowledge and social backgrounds.

4.3.2 Lack of Understanding and Supporting the Convergence

The research found the convergence phase as the most challenging part during the Collaborative-CCA process. The degree of complexities has been increased due to the convergence phase and the lack of support let the users in difficult endeavour. In this research, we intended to explore this challenge further by focusing more on the convergence phase in the collaborative settings. In order to do that, we must review and get a deeper understanding on how convergence works and how the involvement with other phases need to be taken. We found the studies from the circle of research below complement our understanding about the convergence challenge during the collaboration process from the complex cognitive activities point of view:

Main Ideas about convergence	**Sources**
Convergence in the collaboration	Kalfschoten & Brazier (2012), Briggs et. al (2011), Kalfschoten (2012)
Identified big picture challenges during collaboration process for experts and decision makers in knowledge integration:	Mengis & Eppler (2006, 2007, 2008), Eppler (2004, 2006a, 2006b, 2011a, 2011b, 2012), Eppler & Bresciani (2013), Eppler & Burkhard (2005, 2007) Eppler et al. (2004, 2008, 2011), Mengis, (2007a, 2007b), (Mengis & Eppler, 2006, 2007, 2008)
The iteration between abstraction (converge) and details (divergence) for higher level of thinking.	Ziemkiewicz (2010),Ziemkiewicz & Kosara (2008, 2009, 2010),
The importance of user's goal, target and objectives	Albers (2004, 2008, 2010, 2015)

From the above LR, the research has identified two factor that cause challenge during the convergence phase, which are: a) Understanding the main drivers and b) understand the interconnection between various elements. Each will be described in the following paragraph.

a Understanding the Main Drivers

The first element of the convergence challenge is to understand what to achieve and even more challenging is how to stick to that vision throughout the Collaborative-CCA process. Understanding the main drivers has become the challenge during Collaborative-CCA because they are: i). No centralized guidelines among the users, ii). Difficulties to appreciate the collaborative value, and iii) difficulties to sustain the main driver's direction.

First of all, there are no centralized guidelines among the users. This is the key to miscommunication. According to Eppler et al. (2004) and Mengis (2007), each of the collaborator has a different mental model and a very specific view on the issue. They are often not able to envision the big picture of a solution or decision on their own, but have to integrate both perspectives. In this situation, the main driver should be open enough to another perspective and to see the interconnections between the different perspectives and points of view.

Alliance (2015) highlights the difficulties to appreciate the value of the main driver because the users have trouble balancing the collaboration needs with self-interests. The vision dilemma centres upon the confusion over the ecological focus of the group since an individual has different missions, priorities, constraints and interests. In relation to the previous discussion about context dependent, the differences between the users in terms of roles, their knowledge level and social backgrounds build different mental models. Thus, the collaboration purposes are being viewed from different angles and perspectives. However, individual mission always comes first in the collaboration. The users would work if the group mission is fit or overlaps with theirs. Then, setting priorities does not necessarily work since to set and agree on the same priorities are difficult.

Finding a common agenda that is worth one's while in the collaboration is the better mission in the collaboration. Furthermore, it reflects the real value of collaboration, serving as a major influence and guideline on each of the users' behaviour and attitude during the CCA. Hence, it is difficult to emphasize the real

value in the collaboration since there are different mental models. Each mental model perceives and assumes a different value that is biased on their own interest which sometimes contradicts the real value of collaboration. By letting them question the 'how' and 'why' during the convergence main drivers, it will help to rationalize and balancing heir own value in order to achieve the shared of collaborative-CCA values.

Lastly, to sustain the direction on main drivers is difficult due to the interchanging of the conceptual in Collaborative-CCA. According to Roschelle (1992), during the collaboration process, there will be a new conception of pulling, disagreeing with the old conception and suggesting that a conceptual change has occurred, especially when discussing the complex cognitive issues. According to Mengis (2007a), sometimes they understand at the beginning of the process, then lose themselves during the collaboration process due to the interchanging of conceptions.

b Understanding the Interconnection

Understanding the interconnection is the capability to relate or join different elements to be meaningful as an integrative one. Interconnection has become the challenge during Collaborative-CCA because elements come from various level and details and the nature of CCA and collaboration themselves.

Interconnection between various elements that come from various level and details have become the main challenge during the convergence process. This challenge has been thoroughly investigated by Mengis & Eppler (2007). They term the challenge as 'the big picture' and highlight the difficult challenge of gaining and sustaining the big picture between experts and decision makers in the collaboration settings. According to Eppler (2012), the experts and decision makers as the users have the feeling of being stuck in a sea of technical details to which they do not know how it relates to the more general issue that is the object of decision.

Mengis (2007a; 2007b) further describes the challenge to converge is the difficulty to gain and keep an adequate overview of the CCA. It is related to the capacity to see and draw interconnection and to find an adequate level of detail or

abstraction by identifying its main drivers and the interconnections between them, while paying sufficient attention to its relevant details. During the convergence, the users have to see the interconnections between the various perspectives they bring into the discussion, between the specific issue on which they have to decide and the larger context in which it is embedded. Thus, in making the decision or solving the problem, the users find the difficulties and cognitive overload to synthesize from various point of views and the range of pertinent aspects in order to finally understand how these different elements interrelate with each other and form an integrative whole as a new idea or the solution.

Elements from various levels of detail and abstraction let the interconnection processes to be more difficult. Too much details leads to disorientations and a feeling of a loss of time and a lack of pertinence. In many cases, the users cannot simply adopt such a top-down method but the convergence is formed by small details so the challenge is not simply to understand the big threads of an issue, but also the small details of which they are made (Mengis, 2007a citing Sull et al. 2005). Providing details is often necessary to understand a more abstract concept, to see the implications of an issue, and to comprehend whether a certain solution is feasible or not. Rhodes argues on this purpose that “one of the most common reasons for being off the mark is operating on the wrong level or scale” (Mengis 2007a citing Rhodes 1991) and not marking clearly on which level of detail one is operating. It is not self-evident to judge upon the importance and pertinence of a piece of information and to determine the adequate level of detail. Experts, with their very domain specific but profound knowledge, perceive something still quite abrasive and superficial while for the decision makers, it is already extremely specific and too rich in detail.

The increasing complexities in the collaboration settings are also related to the process of CCA and the collaboration nature themselves. According to (Krathwohl, 2002), for easier understanding, the complexities of CCA will be reduced to simpler and more fundamental elements. After the understanding, these simpler elements will be converged again according to the main driver. At this point, Mengis (2007a) highlights the increasing of complexities is related to the challenge to see the links between:

- The causes of an issue,
- The causes and their symptoms.
- What user A said a minute ago and what B said just a moments ago
- Certain statement relates to another
- Level of abstraction one is moving
- Certain technical detail of the problem refers to one of its more general drivers

Hence, in collaborative settings, the above complexities increase due to more linkage elements since more ideas emerge from more than one user. Each of the users holds one or more key points, then the higher-leveled key points lead to a higher level of complexity during the perspective and key points change. In that case, more elements need to be reduced and converged and accumulating a greater cognitive effort to compare, analyse and synthesize in order to achieve the main driver. Further than that, due to the limited capacity of human memory, the elements need to be reduced to the manageable size according to the human memory capacity. Since the human memory capacity is only able to hold seven and plus minus two elements (Miller, 1956), then the user will find trouble and feel uncertain about which elements to keep and which to deduct during the remembering phase. It lets the users hold and remember as many elements as they can. As a result, the performance decrease for the interrelated phases –analysis and decision making.

4.3.3 Evolvement of Collective Knowledge

As discussed previously, the information items can derive from complicated and complex manners. Even though the complicated information is messy, massive and diverse, they are still manageable to be handled in a sophisticated and determined manner. Nevertheless, we emphasize our concern on the information trend in the Collaborative-CCA process towards an emerging item that is not within the system control – the emergence. According to Johnson (2010), basically, emergence refers to the ability of low-level components of a system or community to be self-organized into a higher-level system of sophistication. The emergence is the creation of a new

level organization through the coming into existence of one or more self-sustaining systems or agents. From collaboration perspectives, there is an increasing of emergence since each of the users will contribute as an agent in the population.

There are differences in understanding emergence – some view emergence from the perspective of synergies, concept, process, perception, structure and enigmatic. However for this particular research, we refer to Roger Sperry and Donald Campbell who clarify the significance of emergence for mental and cognitive perspectives (Corning, 2002). Thus, in facilitating CCA, especially in the collaborative settings, we need to bear in mind that the information is not only directly from the computer, however, the emergence of information should be concerned of the perspectives of: a). The input - information to feed the users' cognitive process and b). The output - new interpretation from each of the collaborator's cognitive process that is evolving during the performance of collaborative CCA.

a The Evolvement of Collective Input for Cognitive Process

The input is the information to feed the cognitive process. Hodgson (2009) emphasizes the homomorphism of the mental model becoming the subconscious assumption of the world as it really is. Thus, the transaction between users' mental models and information space is important during the cognitive induction. For each of the ideation, the collaboration process forms from the perspective of cognitive. During the divergence, the users rapidly gather, share or brainstorm the information from varying relevance, across multiple levels of abstraction and of varying granularity. In consequences, collective information from the information space evolves during the process and continually emerges since the interpretations during the cognitive process require relevant information. This happens because when the impact of the uncertainties is at its optimum level, the users are willing to entertain alternate views. Thus, new situations require new cognitive rules of interpretation, hence, it requires the emerging of new information from the information space to deepen the understanding, and to further compare, apply, analyse, relate and finally induce new knowledge that must be relevant to accomplish the collaborative CCA goal.

b The Evolvement of Collective Output from the Cognitive Process

The output is a new interpretation from each of the collaborator's cognitive process. Besides the evolving of information from the information space to feed the cognitive process, the users also face the emergence challenge of a new knowledge from the induction of their own cognitive process. New knowledge results from the constructive alignment of the new information along with the current knowledge in the mental model. For the induction process, each of the interpretation from the mental model contributes as new knowledge (for instance: ideas, suggestion, analysis and recommendation) for alternation. For collaboration CCA, the information that is shared and created by a group during the divergence phase needs to be converged to a manageable size to create an overview of its content in order to make it useful for further analysis, evaluation or decision making. According to Kalfschoten & Brazier (2012), the transition from the phase of divergence to convergence causes cognitive overload among the users since they have multiple tasks. For the first stage, they need to capture and memorize the information from the information space. Then, the processes of preparation and analysis are required during the transition from the phase of divergence to convergence. Through these activities, the cognitive elements of reductionism, shared understanding, classification and overview are essential to process the collective information to be outcomes for collaborative CCA. Moreover, the cognitive load is getting heavier since the users need to catch up for newly emerged information from time to time during the performance of collaborative CCA.

Due to the collaborative settings, we have seen the increasing of emergence elements occuring during the CCA and especially during the involvement between divergence-convergence phases. Thus, it raise the complexities of visualization in representing the complexities in terms of:

i The Constructive and Evolvement of Information

Since the convergence phase require the capabilities to combine the elements from various level and sources to form a connected whole, then the information is evolving throughout the process. The assimilation between the newly emerged information with

the previous information constructs a new information that lets the process of Collaborative-CCA evolve gradually. As an example, the output from one collaborator's cognitive process, may be the input for another collaborator's cognitive process. In this situation, it is essential for the users to respond and act according to emerging information items to stay relevant during the complex activities process. To do that, each of the user needs to assimilate with emergent information items, align with what they have in hand and construct new outcomes that further constructs in the process.

ii Iterative Looping between Divergence-Convergence and Convergence-Decision Phases.

The emergence element lets the sustaining and gaining the interconnections between elements become more critical throughout the whole collaborative for CCA process. Since the convergence phase is looping iteratively between the divergence-convergence phase and convergence-decision phase, then the crucial part is to gain and keep an adequate overview and the interconnections between the convergence phase and other phases during the Collaborative-CCA process.

4.4 THE FINDINGS FROM SEMI STRUCTURED INTERVIEW

The previous section has highlighted three intersection challenges of Collaborative-CCA that are significant in the collaboration settings. Within this section, the research intends to get a deeper understanding about how the challenges are being taken in the real organization. From the method of semi-structured interview (please revisit the methodological perspectives in section 3.4), the research intends to verify the occurrence of identified challenges from the real organization settings. If it occurs, then using description and task settings from the real users' own job perspectives, this research aims to enrich and expand the description for each of the challenges and how it gives impact in their real work.

In order to verify the challenges from organizational settings, the research use the challenges foundation developed from LR as the criteria. Generally, findings from

the interview have justified the challenges from the LR in the real organization settings. However, instead of describing the problem, the data from the participants more likely described the situation that happened and the effect of the condition towards the Collaborative-CCA process, output and impact on their job. In the next paragraph, the findings from the interviews will be described in details.

4.4.1 Theme 1 - Different Mental Model in Achieving a Shared Goal

From the analysis, the result has justified that the background of users have given impact to the CCA process and outcomes. When CCA occur in collaborative settings, most of the participants admit that the distinguished character for each of the collaborator is due to their background and these differences will lead to the different mental models among the users.

a Different Roles of Users

Table 4.4 summarizes the impact and ideas extracted for the subtheme of different roles of users. Through the corresponding key ideas, we develop the sub-subtheme as in Table 4.4 to support the subtheme for different roles of users.

Table 4.4 Sub-subtheme and Corresponding Key Ideas in Supporting the Subtheme of Different Roles of the Users.

Subtheme	Sub-subtheme	Corresponding key ideas
(a). Different roles of the users	i) Guidance is depending on the roles of the chairperson and secretariat.	• The Collaborative-CCA process and outcomes are depending on the roles of the leader and secretariat. • Other users are playing a passive mode during the collaboration (especially on the directive process).
	ii) The quality outcomes is depending on the roles, knowledge and skills of the users	• Experience help a lot during the collaborative process because cognitive backgrounds through experience helps the users about the how knowledge and easily • The valuable and quality of the decision (outcomes) rely more on the context and the background of the users – because they know the how knowledge (context) and content knowledge
	iii) The significant of secretariat roles especially in the multi level of collaborative CCA	• Secretariat play an important roles to manage the Collaborative-CCA • The Collaborative-CCA process takes place from lower to higher level of the Collaborative-CCA
	iv) The differences between experts and decision makers view	• Decision Makers mostly involves the whole/various field of expertise while SME/Experts mostly focus on the experts.

i) The role of leader, chairperson or the boss is extremely important during Collaborative-CCA. Most of the participants agreed that the guidance for Collaborative-CCA relies on how the chairperson plays the role during the CCA process. PID3 highlighted the roles of chairperson as the moderator and PID4 said that *"the wise role play of the chairperson to control the meetings. First, the timing structure – so that the process is not dragging. Second, the sharp content and not discussing irrelevant topics. Then, the chairperson must know how to make the discussion alive and not too dry – that is able to get opinion from the meeting members (the users)"*. By understanding that the major roles of the chairperson are the controller and moderator, the research also found the influence of a chairperson to guide the Collaborative-CCA to achieve a better value of the outcomes. However, the research also found the critics of having an incapable chairperson that contributes to an ineffective CCA process and outcomes. According to this issue, PID6 said *"the roles of the chairperson will determine the success of the meeting. He must have a stand and not be too lenient… or the others will feel unguided"*.

ii) Since the incoming issue in CCA is very uncertain and they don't have any clear guidelines to follow during the process, then the Collaborative-CCA need to rely more on the context and backgrounds of the users to come out with valuable and better outcomes. According to PID5, "*…the issue to be solved is not like an operation task, which you can have rigid and details of SOP (Standard of Operating Procedures) to follow. This… (referring to the operation task) everybody can do it… instead of the higher level issue, the solution has to come from the wisdom advice through experienced SME (Subject Matter Experts)".* From this statement, we understand that the outcomes for the CCA is depending on the users' context as guidelines and contents. Thus, it is essential for CCA to have a variety of users' context. By having various users, the CCA have the potential to get an opinion, perspectives or mandates (PID4 used the term "mandate" for this point) from the parties concerned. Normally, the users are come from different unit, fields or departments which reflect a various roles, knowledge and styles.

iii). One of the interesting finding is the significant roles of the secretariat to manage and strategize the CCA. The participants, especially from multi-level collaborations

like the international level, who interlink between different agencies and departments have highlighted the importance of the secretariat to drive the Collaborative-CCA. In most of the important committee, the secretariat is basically a form of the SME (Subject Matter Expert) which is synonymous to a 'knowledge bank' that holds the knowledge for the CCA in its specific subject matters and fields. Then the process of Collaborative-CCA is taking place from the executive level up to the higher level, in which the Collaborative-CCA is taking place from secretariat level (usually, the unit – subject matter experts) up to the higher management level. It has been an iterative and refining session throughout the levels. Most of the participants agreed that most of the time, the highest level meeting is only the finale for formal endorsement. Thus, this kind of meeting is looking from the overview perspectives and expects good suggestions and a comprehensive solutions must be tabled up from the secretariat members. As examples, the participants mentioned that:

> *"yes… the meeting is for endorsement purpose, to come up with a suggestion is the secretariat's role, or as in the international meeting, we call it pre-counsel"* (PID4)

> *"The chairperson has a lot of things to do, think and remember, They surely don't have time to think of this complex matter"*(PID10)

> *"When in the higher level meeting, the chairperson and members will ask for us (refer to the secretariat members) to add or change (the proposed solution). Because they don't want to think, they want us to come and dump all the suggestions while and they just make the decision. It is their style, they don't have time. So many things to do… then we (refer to herself and her team as secretariats) help to think for them"* (PID9).

From here, it is clear that the facilitation for Collaborative-CCA is worth of all the stages during the Collaborative-CCA process. It is needed for the secretariat up to the highest level of collaboration. To come out with the quality of Collaborative-CCA outcomes, the process for Collaborative-CCA needs to be guided along the way. By

having good guidance, the lower level of Collaborative-CCA may have the potential to come out with valuable and comprehensive suggestions for the higher level.

iv). From the analysis, the research found the distinct requirements between experts and decision makers that lead to more conflict during Collaborative-CCA. The experts are usually involved with issues mostly related to their expertise and focus. It is mostly within one expertise field, environment, knowledge, skills and key points. Thus the concept of the incoming issues is similar with the previous case. PID1, PID2 and PID5 agreed that the big picture is useful to initially understand their job scope and the environments. Once understood, they will drill down on the issue by themselves. After doing a few cycles of work flow, it becomes a routine. Therefore they understand and know how to handle similar incoming issues. On the other hand, the decision makers are mostly involved in multiple fields. It consists of new solutions, ideas, innovations, decision making and evaluations. Hence it is more abstract and interrelated among various expertise and perspectives. The decision makers need to combine all the key points from relevant fields based on the incoming issues requirements.

From the statement above, it shows that there is a distinct requirement between experts and decision makers. The pattern on incoming issues for experts mostly focuses on the certain field of expertise, therefore it is similar and go in depth. On the other hand, decision makers need to understand the interconnections and relationship between key points from multiple field expertise in order to finally understand how there different elements interrelate with each other and form and integrative as a whole, in which it is unique and complex. In this situation, the conflict raise since the decision makers will become blurr when disccussing details issues while the experts difficult to see the value of importance of other's expertise point of view. The differences between the depth of knowledge (details) and wide of knowledge (interrelationship between different fields of expertise) let the users' difficult to understand each other's point of view.

b Different Level of Knowledge

Table 4.5 summarizes the impact and ideas extracted for the subtheme of different roles of users. Through the corresponding key ideas, we develop the sub-subtheme as in Table 4.5 to support this subtheme.

Table 4.5 Sub-subtheme and Corresponding Key Ideas in Supporting the Subtheme of Different Level of Knowledge.

Subtheme	Sub-subtheme	Corresponding key ideas
Different level of knowledge	i) Know the content	• Experiences help to develop the expertise in certain subject matter. • Know the content –let the users being knowledgeable in that area. • The knowledegeable collaborator is valuable in the process.
	ii) Know the context	• Experiences help to know what step to be taken in order to handle the Collaborative-CCA process like decision making or problem solving. • Know where to refer, who are the people in charge and which policy to be considered
	iii).Group members who don't know	• The collaborator in the group keeps quiet because they don't know what to ask and how to get involved (being passive-'ahli tidur') • Lead for trial and error solution • The collaborator in the group keeps quiet even when they know because the superior doesn't know - they keep silent to maintain the boss reputation (status quo)

i). The result shows that working experience gives credit to the user's knowledge development. Having a few years of working help in two ways: content and context of the knowledge. As mentioned by PID1, he said that *"it was hard to understand the overall situation but after gaining a few years of working experience, it is a lot easier now….. Most of the angles, perspectives and knowledge are in my head"*. Further than that, the learning also help the people to develop the knowledge content on the specific area or as most of them term it, the 'Subject Matter Experts (SME)'. This kind of knowledge is essential to produce valuable outcomes during the Collaborative-CCA.

ii). In the other way, experience also help the users to develop the knowledge context, which means they know how to handle the Collaborative-CCA. By attending and getting involved in various kinds of Collaborative-CCA, the people are able to know

what step to be taken in order to produce valuable outcomes, how to handle the conflict and yet develop constructive arguments between the users and who to refer and which policy to consider. According to respondent 5, this kind of knowledge is more precious compared to the SME. Most of the time, only most experienced people are able to do this. That's why they need to have the experienced people to advice during Collaborative-CCA.

iii). Due to the norm of organization, the people involved in the Collaborative-CCA are a variety, from the executives to the middle management to the higher level of management all of whom are have various backgrounds, positions, roles and levels. Some of them are new in the job and inadequate of knowledge in terms of context or content. This leads the Collaborative-CCA having passive group members, in which the PID5 and PID3 termed them as 'ahli tidur'. This kind of situation gave unproductive process and outcomes to the group. Even though, they are led by good and experienced leader but then the value of collaborative doesn't take place, which leads to the 'one man show' and the other group members don't play a good role in providing the quality of the outcomes. It becones worse when they are all new, and when they need to deal with an uncertain matter, they may come out with the trial and error approach. As mentioned by PID7 *"...when the boss doesn't know the direction, the staff also doesn't know what to do, so then, we will do what we feel is right - trial and error".*

Second, the interactivity is quite passive among the users when discussing with the higher rankings. Throughout the peer-review session, the peer explained the possibilities of the passiveness due to the Malaysian culture that is sensitive and avoids conflict to cover the boss and colleagues reputations. Especially for the higher level of CCA meetings, only the bosses with the same level and positions actively communicate. The other participants, especially from lower ranks mostly keep quiet and listen. As mentioned by PID4 and PID6, if they have an opinion and ideas, they will find an alliance among the leaders whom they are comfortable with, then the opinion and ideas are being channelled through them. This situation however, develops less effective CCA's constructive arguments and outcomes, especially when the collaborator has knowledge about the CCA but is a lower rank position, with the

most prominent example being between business and technical collaboration. According to PID3 and PID6, business people usually hold the higher position while technical people are of the lower position. Even though, the technical people hold more knowledge about the situation, the business people hold more power. The differences of ranks let the technical people feel awkward during the CCA process. When in the collaboration, it is difficult for a technical person tp try explaining the issue which business people can't see. According to PID5, *"the blurriness cum ego let the point of talking faded away"*. Sometimes, technical people feel like they don't have any say in the discussion. If they do, it may drop the boss' reputation, jeopardize their career and develop conflict in their longer term of relationship.

c Different Skill of Communication, Type of Learning and Background.

The research found the factors of skills that make the differences in Collaborative-CCA. The participants mentioned the importance of communication and negotiation skills to convince each other during Collaborative-CCA to make a difference in the outcomes. Further than that, personalizations like persona and good 'aura' also contribute to the outcomes of the process. Since, the research is not focusing on these elements, the personalization findings from NCA will not be emphasize as a new theme, hence included into this subtheme (different skills of communication, type of learning and background).

d Pattern of Incoming Issue

The research found the difficulty of Collaborative-CCA is that the pattern of the incoming issue is very unpredictable and uncertain. The uniqueness of the incoming issue is like a new solution, idea, innovation, decision making or evaluation that needs to be done according to certain domains and circumstances. These kinds of uncertainties need to be presented, digested and understood as the shared goal among the users. After understanding the goals, then all the knowledge content and context, roles and perspectives need to be amended according to the shared goal.

4.4.2 Theme 2 - Lack of Understanding about the Importance of Convergence

The element of convergence had been asked to the participant multiple times according to their situation throughout the interview. This is because, the researcher wanted to make sure the participant was able to grab the question rightly. Table 4.6 summarizes the corresponding key ideas in supporting each of the subthemes. Basically we were able to identify similar key ideas to perform two subthemes to support the second criteria (theme 2).

Table 4.6 Subthemes and Corresponding Sub-Subtheme to Support the Theme 2

Main Challenges	Subtheme	Sub-subtheme (from DQA)
Second criteria (Theme 2). The lack of understanding of the importance of convergence	(a) The difficulties to clarify the main driver	i) The main driver is instructive (too tight) or abstractive (too loose) ii) Difficulties to appreciate the value of main drivers iii) Difficulties to sustain the main driver direction
	(b) Difficulties to see and draw the interconnection between various elements.	i) Separative job oriented thinking ii) The users are in the determination approach iii) No guidelines during higher level thinking iv) Mental Overload v) Seeking and searching from various tools usage (sources)

From the analysis, the research has identified the occurrence of the pre-requisite of convergence – the divergence phase during the collaborative CCA. Most of the participants agreed with the importance of ideation process which is carried out by asking opinions, getting feedback, listing out the suggestions or dumping a set of proposals during the collaborative CCA. However, we sensed a lack of understanding and implementation of convergence during the Collaborative-CCA due to the difficulty to digest the main driver because of the: i) instructive (too tight) or abstractive (too loose) of the main drivers to centralized and externalized the guidelines, ii) difficulties to appreciate the value of the main driver and iii) difficulties to sustain the main drivers' direction. More over, the analysis found 5 sub-themes to support the theme of the difficulties to see and draw the interconnection between various elements. The sub-themes are: i) Separative job oriented thinking, ii) the users are in the determination approach, iii). No guidelines during higher level thinking, iv). Mental Overload and v) Seeking and searching from various tools usage (sources). Each of the sub-themes will be described briefly in the next paragraph:

a The Difficulties to Clarify the Main Driver

The research found the clustering of key items as shown in Table 4.7 to develop the 3 sub-subthemes of the difficulties to clarify the main driver. Generally, from the analysis, all the participants have clearly answered and highlighted the importance of the main driver which they termed as purpose, aim, objective and agenda during the interviews. The job only can be done after they identify the specific issue or problem that needed to be solved. As an example, PID2 mentioned that she needed to know what the purpose is or issues are before identifying the related elements. One more example is mentioned by PID3, *"The agenda must be outline… early in the meeting. They must clarify the aim and hasrat jabatan. Then get some feedback from the other departments (means the users). Only you must very clear on what you want"*Therefore, it is clear that the participants need to clearly understand the main drivers before the Collaborative-CCA process.

Table 4.7 Sub-subtheme and corresponding key items in supporting the difficulties to clarify the main driver

Sub-theme	Sub-subthemes	Key Items
(a)The difficulties to clarify the main driver	i) The main driver is instructive (too tight) or abstractive (too loose).	• The abstractive objective as the main driver give less guidance to centralize and externalize their shared mental model. • The instructive main driver has the potential to lead the CCA being handled in determination approach.
	ii) Difficulties to appreciate the value of main drivers	• Value for CCA process is more on finishing the task instead of solving the CCA • Care about the value and benefit of outcome due to their own self interest.
	iii) Difficulties to sustain the main driver direction	• Deviation during more increasing complexities. • Blurriness (being clueless) when others talk about their field of expertise (too detailed, too deep). • At a lost when the chairperson is unable to control the discussion • At a Lost when the chairperson is incapable of summarizing the content of discussion.

i). Most of the time, for new and complex matters, the objective as the main driver is abstract and too general and lets the collaboration process be too loose, leading to unrelated content of discussion. When the main driver is too loose, the users don't feel

like they have the guidelines to centralize and externalize their shared mental model. In contrast, the research also sensed the needs to direct and determine main drivers during the collaborative CCA. As example, the participants have mentioned that:

> *"You must be clear of what you intend to achieve towards the end of the meeting. Don't let this meeting lead to another meeting."*

> *"A good meeting is a meeting already designed to get the decision in favour to your needs."*

The instructive main driver has the potential to lead the CCA being handled in a determination approach. In the determination approach, being open for convergence may delay the task and job execution. However, without understanding the real value of the main driver, the users tend to aim for job completion instead of solving the complex issues. The research identified the reactive mode of the users that insist to achieve the instructive objective of the Collaborative-CCA without reflecting on the CCA values. As an example, the PID4 said *"let's say the tender meeting has 4 papers. Does this paper fail or pass? Does this paper fail or pass? Then, case closed"*. Here, the users mostly want to have a clear and instructive objective and finish the job. When asking about the elements to consider during the approval, they based it on the checklist of policy, budget constraints and technical specification. When asked, *"Is there anything else to consider?"* they simply answer that it is out of their scope of work. By insisting on an instructive and directive main driver, there might be a possibility for the mismatch on 'how to conduct knowledge', leading the complex activities to be tackled by using purposive and determined approaches.

ii). However, to understand the real value of the Collaborative-CCA is not an easy task. PID8 told that as the ICT Department Director, she previously had trouble to identify what the decision makers really need from the ICT department. After understanding the real needs from the business perspective, she is more guided on what to do, where to go and why the ICT Department needs to do the job. The research only found four out of ten participants who are capable of appreciating and connecting the value of interconnection in solving the CCA. As an example, the

response from the PIDs in Table 4.8 below highlighted the differences values according to the main drivers' consideration

Table 4.8 The Differences Values According to the Convergence Consideration

Without convergence considerations	**With convergence considerations**
Choose the best tenderer on the tender evaluation based on the criteria given.	Instead of choosing the best tenderer on tender evaluation, they mix and match the tenderer expertise in forming one project. thus, most of the tenderers will sustain throughout the economy recession.
Example: *Let's say the tender meeting has 4 papers. Does this paper fail or pass? Does this paper fail or pass? Then, case closed". (PID4)*	Example: *The agency divided 27 boats tender to the 3 companies. Then, by having 9 boats project, each of the company is able to survive at least for one year during this economic struggles. It also benefit back to the agency... because each of the company is performing well when they feel competitive with each other. They make sure to deliver the boats on time and achieve the speed and be the best for technical specification (PID1).*
The outcomes for tender decision is straightforward and relying more on determined consequences like a policy, criteria of technical and financial.	The outcomes for tender decision have been more valuable since it reflects the value of the tender approval tasks to the vendors, agencies, economy cycle and the nation as well.
An isolated strategy plan from different agencies in one ministry for another 5 years planning. *Example:* *Each of the ministry agencies in KPKT (Kementerian Perumahan dan Kerajaan Tempatan) must come out with different strategy plan (Participant 5)*	An integrated strategy plan for different agencies in one ministry to provide better value for the stakeholders. *Example:* *The strategy planning for KPKT (Kementerian Perumahan dan Kerajaan Tempatan) as one ministry being executed from different agencies – Thus, the agencies (JPAS, JBomba, JLN and house developers) must complement each other to form a comprehensive and sustainability of house development and living (Participant 5).*
The outcomes for strategy plan is dependent on each of the agencies towards the ministry, without sitting together, collaborating and considering how their strategy can reflect the stakeholders better and eliminate redundancies between the agencies.	The outcomes for strategy plan is integrative from ministry level to each of the agencies. This master plan will help each of the agencies to hold the responsibility with the connection with each other and able to contribute better for the stakeholders.

iii). Based on the analysis, the difficulty to sustain the main driver's direction is when the discussion becomes more profound, deeper and related to various levels of depth, especially when they are disscussing about a certain expertise that is irrelevant to all the users. Thus, the users are unable to relate the specific discussion to the main point of the discussion, leading to being clueless and deviation from the actual main drivers. The deviation and lost of the main driver will become worse when the chairperson is unable to control the discussion and incapable of summarizing the content of discussion.

b The Difficulties to See and Draw the Interconnectedness

From the analysis, the research found the cluster of key items as shown in Table 4.9 to develop the 4 sub-subthemes to justify the lacking for an integrative solution.

Table 4.9 Sub-subtheme and Corresponding Key Items in Supporting the Difficulties to See and Draw the Interconnectedness.

Sub-theme	Sub-subtheme	Key Items
(b) The difficulties to see and draw the interconnectedness of information.	i) Various and multi sources of information.	• Information come from various and multisources. • Different experts, units, departments hold different ownership of information. • More concerned about their self interest (e.g. their individual, representing unit, department or agencies) compared to the shared vision, • Being open for convergence might jeopardize their self-interest. Since they don't see, they don't care for others' interests.
	ii) The users are in the determination approach	• The users aim for job completion instead of value in handling the CCA. • Open for convergence may delay the task and job execution.
	iii) No guidelines during higher level thinking (convergence)	• Need an explicit reminder and reference throughout the process (e.g, memorandum, tentative and agenda) • No supporting tools while doing the higher level thinking • The higher level thinking happens in the user's head / in silo. • Less of constructive arguments and reasoning – why and how for each of the consideration
	iv) Mental Overload (convergence)	• Too much information and it is difficult to be written (they don't know what to write) • Unsure which information to drop. • Too complex, so the users tend to focus on what they are able to understand and ignore the rest.

The research found that the users is having difficulties to understand the interconnection between various elements in different level of abstraction and details because the sources of information is came from variety and multi-sources. Each departments will have different kind of information ownership. Since the users are in separative job oriented thinking and information from different department was not under their control, it is difficult to see and understand the interconnection between these kind of various information. Furthermore, the users are concerned about their self interest (e.g. their individual, representing unit, department or agencies) compared

to the shared vision, thus being open for convergence might jeopardize their self-interest. Since they don't see, they don't care for others' interests.

It was quite common for the researcher to get the puzzled faces and long waited answers when the researcher was asking about the interconnection elements within the solution. Some participants could not understand why they need to have an integrative solution and some worried about the impact of the integrative solution as not focusing to their agencies' needs and mandates. As an example, the PID4 looked puzzled when answering about the integrative solution and said *"… the solution from multiple agencies? It will turn out to be…. messed up (sudahnya… rojak).* Further than that, the research also can understand the worries of convergence to delay their task in hand or being too open that might jeopardize their own interest during the Collaborative-CCA. As an example, PID6 said,*"Normally, what do you want to achieve? If you want a solution, then you go for the round table, asking people for solution, you will get it… if there are ten people, then ten solutions. It seems like the objective of the meeting is not clear.."* and PID6 said, *"If there is a problem, you ask five people in the group… don't be open to everybody, you must have a stand and instruct - you do this"* Here, the participant still insisted on a clear and instructive objective. However, this kind of instruction instead of discussion process, the point of consideration has been focused only on certain elements which lead to the lessening of interconnection and holism during the convergence.

Asking further about the question from the previous scenario given, like *"Don't you consider that 10 ideas should be converged to become one comprehensive solution? At that time, maybe some ideas need to be rejected and some ideas may have points to be considered"*, led the participants to usually refer to the capability of the chairperson or secretariat to come up with an integrative, innovative and comprehensive solution. As an example, PID7 agreed with the point but she said *"It is difficult to merge a few options to get the best result… not many people like that. It is the problem".* There is a participant who answered about the naturally talented and experienced leader who is able to come up with the interconnection and various points of consideration to conclude the solution. However, this kind of leader mostly holds a higher level of position. However, during the higher level meetings, there is a massive

amount of CCA issues to consider and each of it is messy, which an experienced leader doesn't have an ample time to look for each of it. It turns out the responsibility to handle the CCA has been given to the secretariat in the middle management. Since, some of the secretariat in middle management is still following orders, lacks experience to handle the situation from various perspectives and is specific task oriented, then it comes to justify the confusion of why they need the instructive main driver as described above. Thus, they are keen on the determination approach to handle a complex situation. Even though this kind of determination practice is relevant to the complicated matters, but it is a mismatch to handle complex matters. This mismatch causes an instructive instead of constructive process of CCA. It reduces the interactivity and arguments among the users which lead to less convergence. Moreover, during the instructive process, the point of consideration has been focused only on certain elements which leads to less interconnection and holism, that are essential for the convergence phase.

The convergence process is in the higher level of cognitive and leads to cognitive overload. PID4 said that "Sometimes when it is too complex, "*I am sketching my own mind map to clear things and get more understanding. The key points and the details that are relevant to the current task are jotted down and then linked if there is a relationship among each other.*" It shows that when it's too complex, the users need the tools to facilitate their thinking. More over, it also shows that the users usually refer to their own mental model without any centralized and externalized guidelines to facilitate them during the convergence phase. Normally, the users are able to propose ideas during the divergence or brainstorming phase and then identify which ideas can complement the main drivers well. Clearly, Collaborative-CCA are missing or ignoring the convergence phase.

4.4.3 Theme 3 - The Evolvement of Collective Emergent Information

The question about how the participants handle the incoming information from multiple sources and then the opinion and interpretation of others had been asked to the participant in order to understand how they handle the evolvement of collective emergent information. Table 4.10 summarizes the corresponding key ideas to develop

the supporting sub-subthemes. Basically we were able to identify similar key ideas to perform three sub-subthemes to support theme 3.

Table 4.10 The sub-subtheme and Corresponding Key Items in supporting the Theme 3

Sub-theme	**Sub-subthemes**	**Key Items**
The evolvement from input and output of the cognitive process	i) Hold a massive amount of evolving information	• The incoming information related to the issue in hand. • Difficulties to organise and stucture the information according to other expertise, level or depth and priorities. • The details are too much to handle. • They don't feel in control on the uncertainty of the information.
	ii) Evolving information without groundings.	• Interchangeable words • Same idea but different wordings. Ideas just being rejected because they don't understand. • Not put in proper words – then the idea seems to be less valuable. • Group members reject the conceptual ideas if not yet detailed on it.
	iii) Abstraction (divergence)	• Not put in proper words – then the idea seems to be less valuable. • Group members reject the conceptual ideas if they are not yet detailed on it.

As the consequences from the evolvement of input and output during the cognitive process, the users are having difficulties to hold a massive amount of the evolving information. During the series of cognitive processes, the users need to handle the evolving of the incoming information in relation to the issue in hand. Due to the massiveness of information, it has been difficult to structure and organise the information according to the other expertise, level of depth and priorities. Most of the time, the users feel the details are too much to handle, they may miss, forget or lose valuable information during the activities, especially when they do not understand different perspectives. It lets them feel uncontrolled about the information as the basis for the cognitive process and decision. Further than that, by letting the evolving information flow without any groundings leads to the redundancies of the information. By having interchangeable words, the same ideas being presented with different wordings, sometimes the other users may even have different misinterpretations on the confusing wordings and ideas. In certain situations, the idea is just rejected since the others find as nonsense (PID2), *"tukang karut"* (PID5) or *"melalut"* (PID8). During the convergence, this situation gets worse if the user is incapable of giving proper and

complete form or summarization. Sometimes, the emergence information from the convergence just being rejected are because the other cannot sense any detail out of it.

4.5 DISCUSSION

Through the ‘why’ investigation in section 2.6, the research found the lack of understanding the root cause of the problem between the intersection of Collaborative and CCA. Even though, some research has emphasizes the increased complexities problem due to complex matter and multiple participants and we found the significant roles of visualization to reduce the analytical processes from the information complexities, yet there is still a lack of understanding for the collaborative settings during the CCA process. Therefore, this research had further investigated these conjunction challenges for better design rationales.

Generally, the methodological point of view in identifying DA1 has been described in section 3.6 and the content of it has been discussed in this chapter. The research identified the challenges by having granularity points from LR as to develop a strong basis and at the same time develop a deeper understanding about why and how the problem became more detailed in the complex-cognitive-collaborative particulars. Then, by interviewing 10 participants through semi structured interview, each of the challenges has been verified and furthermore, we enriched each of the points by gaining deeper understanding about how it gave impact and consequences in the real tasks settings. Eventhough, the Collaborative-CCA Challenges that have been decribed by real organizations demonstrated similarity to the set of challenges from the LR. Hence, the challenges have been described in more details and a deeper perspective especially on the impact and the consequences of the challenges towards the value and quality of the Collaborative-CCA outcomes and the research gained more understanding about how the process of Collaborative-CCA has been doing, the people and roles involved as shown in Table 4.11. Due to the deeper understanding we gained throughout the process, each of the challenges have been synchronize accordingly. Hereafter, each of the challenge will be describe in the next paragraph.

Furthermore, instead of looking for a new emergence theme from the interview, the research focused more on understanding how each of the challenges found in the LR is being coped in a real environment of the Collaborative-CCA process. As a result, an overall finding for each of the challenges has been expanded and explained thoroughly during this section and has been consolidated in Appendix E. Even though DQA results were focusing on the collaborative and complex cognitive activities' perspectives, we did find two emerged themes that are beyond these perspectives through the Negative Case Analysis (NCA). Even though, the research found the significance for the themes of: i) Personalization and ii) Multi-Sources of Information with our current study. Then by referring back to these elements in the LR, we found these topics are too broad and might bring deviation from the cognitive perspectives. Since this thesis is concentrated on complex-cognitive-collaborative and only these three challenges have the strong basis from LR, the research decided to focus only on the above challenges and consider the other challenges for future undertakings. Therefore, instead of presenting them as a new theme, we included them as the subtheme in the remain themes.

Table 4.11 Summary of the Collaborative-CCA Challenges from LR and Semi Structured Interview

Foundation From Literature Analysis		**Verification From Semi Structured Interview**	
(Challenge)	**(Factors)**	**(Description)**	
1. Context of use and group fit necessity ⇩ Different mental model in achieving the shared goal	(a). Different roles	… Guidance by chairperson – dry or livable meeting … good participant – rich discussion. … Experts need *details in depth* while decision on the *'big picture'*	
	(b). Different knowledge	… Know the content – *SME – e.g. procurement, logistic, HR* … Know the context – *how to do – policy, procedure,* … know nothing – *newbies*	
	(c).Different skills – ***Personalization (From NCA)***		
	(d) Dynamic Pattern of incoming issue – align the roles, knowledge and skills to the incoming issue		
2. Lack in supporting convergence ⇩ Lack of understanding **the importance** of convergence	(a) The main driver	i) No centralized guidelines ii) Value of personal > collaboration iii) Difficulties to sustain the main driver	.. Instructive (too tight) or abstractive (too loose). ... Moreover, reductionism > Convergence …discussion being in depth and Evolve
	(b) The difficulties to see and draw the interconnectedness of information.	i) Elements from various level and details – ***Multisources information (From NCA)***	.. Different information ownership – unit, departments, experts
		ii) Difficulties to relate details and overview iii) No guidelines during higher level thinking	.. Too determine and focus on his/hers .. Impact of synthetical process → .. cognitive overloaded
3. The evolvement of emergent information.	(a) Input and (b) output of the cognitive process	.. Impact of too much to remember → cognitive overloaded .. Impact of no groundings guidelines → redundancy information .. Impact of doing abstraction → misinterpretation, not conclusive, 'melalut'	

a Challenge 1 – Different Mental Model in Achieving the Shared Goal

The research amended the challenge 1 from the LR to be congruent with the findings from the verification. Since the research highlighted the cause of different mental models gives challenges (effects) in achieving the shared goal. then the research amend the challenge 1 from "the context of use and group fit neccessity" to "the different mental model in achieving the shared goal".

In challenge 1, from literature analysis, the research found basic foundation on context of use and group fit necessity. However, there are only a brief factors identified as different roles, knowledge and skills that lead to that challenge. Therefore, the elaboration from semi structured interview help us to further

understand why these differences give challenge for this situation. The research found the factors of different roles, knowledge and skills of the users cause different mental models among them. That is why the user in the group might not understand what others say and develop arguments and conflicts of interest because they cannot see the others' point of views. Further than that, by having different levels of knowledge and skills, some users who lack certain knowledge don't have the guidance and points of what they are doing. It might lead the users to feel lost during the conversation and need some reference to guide them during the Collaborative-CCA process. The cause of different mental models effects the process to achieve the shared goal during the collaboration process.

In conjunction with that, the visual design solution must consider to handle different mental models as the root cause of the problem. As the consequences, the solution will improve the effect of achieving the shared goal. Some participants had mentioned the cue of visualization to centralized the mental model and ease the understanding for complex matters. As an example, PID10 mentioned that *"When it comes to a complicated memorandum, the secretariat will come out with the graphic display to ease the understanding among the cabinet… you know, when it is visual – all cabinet members regardless of their level of education and background can easily grab an understanding".* Thus, in developing the visualization, the design must consider the different roles of the users, their different levels of knowledge, skills and more importantly sensitivity to the dynamic pattern of incoming issues.

b Challenge 2 – Lack of Understanding the Importance of Convergence

The research amended the challenge 2 from the LR to be congruent with the findings from the verification by emphasizing the importance of understanding the convergence. Therefore the research amend the challenge from "the lack of supporting the convergence" to "the lack of understanding the importance of convergence".

The literature analysis has found comprehensive foundation for the lack of supporting the convergence. There are two factors - the lack of main driver and interconnection as the cause that impacts the understanding for the convergence

process. As the most complex and difficult aspect in the collaboration, convergence is crucial to synthesize and achieve the desired goal from various levels of the users' mental model, cognitive processes and information. Without seeing the bigger picture, the collaboration might end up with the quality of decision not improving the individual decision. Therefore, it is important to support the users during the convergence phase.

However, the findings from semi structured interviewed make us realized that it was not only the lack of supporting, but the users don't understand and see the importance and value of the convergence process itself. In conjunction with that, the research also found the importance of convergence towards the value and quality of the Collaborative-CCA outcomes. This has been our main concern since we can see the different values and qualities between the outcomes of the Collaborative-CCA with and without convergence consideration. The verification also can see the process of Collaborative-CCA occurring even without the users realising the importance to consider the convergence during the Collaborative-CCA. The norm of gaining instructive main drivers, executing tasks and determining the outcomes leads to the descreasing value of Collaborative-CCA outcomes. More over, the research found the unconciousness of the convergence is because complexity arises when the users are dealing with the information space that is usually made up of elements that are connected at many levels and phases. For today's information abundant society, it is continually growing at accelerated ways and the users need the representation to reflect the dynamic changes, adding further uncertainties to the Collaborative-CCA process. Due to the heavy complexities burden, people tend to ignore the situation and prefer to do something they are familiar with, which things they can see and make sense of.

That is why, the research found the essential of the solution design must be able to represent complexity in a way users can sense some awareness about synthesizing multiple elements. At least, the users are aware of the various elements to consider and relate in order to form valuable and comprehensive for Collaborative-CCA outcomes.

c Challenge 3 - The Evolvement of Emergent Information

We remained challenge 3 since there was no significant change between literature analysis and the verification from semi structured interview. This is because the challenge is theoretical – induction of the cognitive process. The research highlighted the knowledge construction from the input and output of multiple cognitive processes leads to the overload of the users' cognitive to hold a massive amout of evolving information that has a lot of abstraction without any groundings.

Then the verification sense the consequences or impact of the evolving information during the cognitive process. Due to the massiveness of evolving information and too much details to handle, the users need facilitation to help them structure and organize the information and at the same time, hold and extend their working memories. Further than that, the complexities lead to miscommunication and idea rejection especially when other group member cannot sense any logic in the ideas. These show that the solution must be able to ground the emergence evolution. Therefore, By having a visualization solution that can help them to ground the environment, the users are able to self monitor, see and be aware of the information's evolution and at the same assist on knowledge construction.

d The Significant Needs for Collaborative-CCA Facilitation

After identifying these challenges, the research also found some cues on how the solution must work to better facilitate the Collaborative-CCA process. From the verification, we can sense the importance to facilitate and manage the Collaborative-CCA. Most of the time, Collaborative-CCA are lacking talented people as the decision makers, sectretariats or the group members to manage and handle a proper process. So when we have the visual design to facilitate Collaborative-CCA, it will guide the users during the process, organise the overload of information, show and relate the interconnection and resolve the tense among peers. With an explicit view, the outcomes will become more integrated and the solution shall be able to facilititate the directive and time control, guide on the 'how' knowledge, and summarize the output. The participants had mentioned about the facilitation tools to support and explicitly

view the process of the Collaborative-CCA process such as: whiteboard (PID8), Mirosoft Power Point, Microsoft Excel (PID7), structure, graphic and charts (PID10), tabulation (PID8) and table up (PID4). They mentioned the importance of the explicit support to:

- Ease their understanding throughout the Collaborative-CCA process, especially for more complex issues (PID10).
- Hold the collective memory memory during the ideation process (PID8)
- Conclude the Collaborative-CCA content (PID7 and PID8)
- Clarify the before-during-after Collaborative-CCA process
    - Before – show and guide the process during Collaborative-CCA ('how' knowledge, what-to-do list, agenda)
    - During – show the explicit of evolving idea
    - After – clear on the action plan (what to be taken)

4.6 CONCLUSION

The aim of the research is to handle Collaborative-CCA from the human-activity visualization paradigm that lets the research revert back to the origin of the complexities phenomenon to understand the root cause of the problem. Thus, this chapter is meant to understand the root cause of the Collaborative-CCA challenges. By undergo the design process as been highlighted earlier in the section 5.1, the foundation of the Collaborative-CCA challenges have been grounded from credible knowledge base. Within the first step, by using LR- the thesis built up a basis of challenges from a complex system and then specifically to complex cognitive activities. By understanding the collaboration process, complex system, organization concept and complex cognitive activities, the research formed the foundation for the Collaborative-CCA challenges. From this basis, the verification through semi-structured interview tried to understand the challenges by reflecting the LR points from the real organizational perspectives.

As a conclusion, by having a set of Collaborative-CCA challenges, this chapter is meant to achieve the RO1 by answering the RQ1 - What are the problems or issues

that occured in the collaborative settings while performing Complex Cognitive Activities? Hence, by following the DSRM design phase 1 on defining the problem, the research has come with a set of challenges for Collaborative-CCA as the design artifact construct. Furthermore, these contruct will be a rationale to support the development of the VRD in chapter 5.

CHAPTER V

VISUAL REPRESENTATION DESIGN (VRD)

5.1 INTRODUCTION

Chapter 5 is basically to answer one question - How to develop the visual representation design theory and its principles as the solution to facilitate Collaborative-CCA? In this chapter, we intend to answer this question by prescribing the Visual Representaion Design (VRD). Previously in chapter 4, the research had identified and described a set of challenges that clarifies why and how users interpret, communicate and reason have raised challenges during the Collaborative-CCA process. As consequences, this chapter intends to develop and prescribe the visual representation design solution that should be capable of facilitating the identified challenges. However, the visualization solution for the complex domain is not always straightforward as for a simple domain, yet the collaborative-CCA domain is new and kind of novelty in the visualization research. Therefore, the visualization solution must have a strong basis, theories and foundation to substantiate the design theory prescription prescription. In order to do that, by following DSRM, the research identified the visualization solution by these sequential steps:

i. Reflect the collaborative CCA challenges from the perspective of visualization field. As design science is from the technological point of view, March & Smith (1995) say that rather than producing general theoretical knowledge, design science should produce and apply knowledge from the situation in

order to create an effective artefact. Thus, the challenges found in the previous chapter will be reflected from the visualization perspectives.

ii. Develop the Visual Representation Design (VRD) by adapting three convergence aspects of collaboration as a principle for VRD basis. From the DSRM point of view, the thesis will further prescribe the use and development of the kernel theory to propose, justify and execute the VRD process development (Kuechler & Vaishnavi, 2008). Generally, two important phases will be used to prescribe for each of the VRD theory and principles, which are:

- Theories to propose and justify the relevancy of the proposed solution from the challenges arised. By using the Kernel Theories which frequently originate outside the computer supported discipline and advise design solutions. Further than that, Goldkuhl (2004) highlights the importance of the Kernel Theories to provide theoritical grounding for the VRD development.

- Theorizing to develop the visual representation design solution. The theorizing will match, propose and define an effective solution based on the theories proposed. Again, we must bear in mind, the application of the theory must be from the visualization point of view. During this section, we prescribe the development by using the same concept of explaination and discussion. Each of the challenges and the principle construction will be examined in relative isolation while still keeping their necessary relationship as an important aspect in defining the solution.

The sequential steps above have been important during the research design process as summarized in Figure 5.1. By relying on the foundations and methodologies from the knowledge base as stated in that figure, this chapter aim to develop VRD as an outcomes from this research design process.

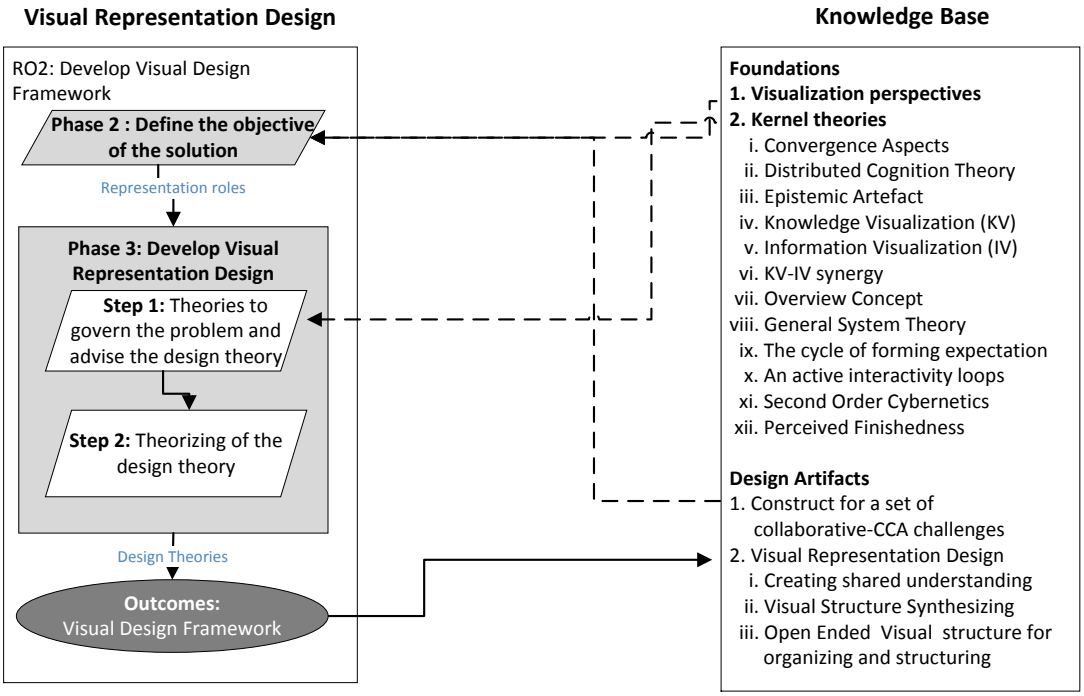


Figure 5.1 Rigor Cycle between the Process to Develop VRD and Knowledge Base.

The structure of this chapter also follows the above sequential steps. In section 5.2, the thesis will reflect the challenges from the visualization perspectives. From here, we define conceptual ideas on how the visualization field can help to handle the problem that has arised in Collaborative-CCA. Then in section 5.3, the thesis will introduce Convergence Visual Representation Design (Converge-VRD) as a backbone for the solution. Further than that, section 5.4-5.6 will further prescribe in details how each of the challenges can be tackled by adapting theory and the theorizing concept. Finally, section 5.7 summarizes the overall development.

5.2 REFLECTION OF THE CHALLENGES FROM VISUALIZATION PERSPECTIVES

We intend to follow the categorization of different spaces similar to what has been proposed by Sedig and colleagues (Sedig et al. 2012a; Sedig & Parsons 2013) as the structured background to address the challenges from the visualization perspectives. Categorizing visualizations according to different spaces can help examine each space in relative isolation while still keeping in mind their necessary relationships, an important aspect in any complex task (please refer to Figure 5.2). For easier review,

the reflection has considered three fundamental spaces: *Mental*, *Representation* and *Information*. Basically, the mental space describes 'who' collaborates and how by facilitating through 'representation' space will help in understanding the complexities of information in the collaborative settings. Each space will be discussed briefly in more detail in the following sections.

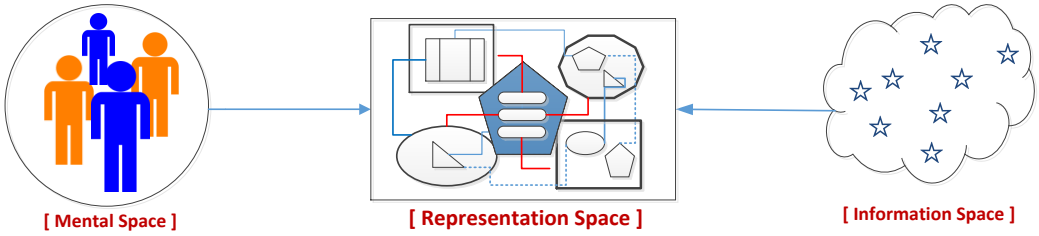


Figure 5.2 The Relationship between the Three Spaces: Mental, Representation and Information (adapted from Sedig & Parsons 2013)

5.2.1 Mental Space

Mental space refers to the space in which internal mental events and operations (e.g. interpretation, apprehension, induction, deduction, memory encoding, memory storage, memory retrieval, judgement and classification) take place. It is mediating reality from people's minds and brains. According to Goswami (2004), a mental space is a core to guide how people handle everything in life. Hence it is where the process of cognitive performs. From the previous chapter, the research has found the Collaborative-CCA happened between distinguished roles, knowledge and backgrounds that make the mental space become more complex since each of the team members have different mental models. Yet, they need to work together in order to accomplish the same goal of collaborative CCA (Mengis & Eppler 2008; Eppler, 2011; Yaacob et al. 2013). Thus it is essential to create an environment where those different mental spaces can be shared and centralized.

Further than that, without a shared and centralized mental space, guidance during the Collaborative-CCA process is depending on the roles of the chairperson and secretariat, while other users are playing a passive mode (especially about the direction of the Collaborative-CCA process). Hence, the reseach also found that the valuable and quality outcomes from Collaborative-CCA also depending on the roles,

knowledge and skills of the users. Ideally, with the proper group members, leader and secretariat that are capable of playing their roles and knowledgeable on the context and the subjects, then the Collaborative-CCA will run smoothly. In spite of this, the research also found the critics of having an incapable chairperson, secretariat and group members that contribute to an ineffective CCA process and outcomes. It leads to the risks of having a trial and error solution, passive users to cover the reputation, 'one man show' situations and having the mismatch of determined versus dynamic solutions. Thus the centralized mental spaces are also playing a role as the guidelines during the Collaborative-CCA. It can help to assist the leader in moderating the process, explicit the 'how' knowledge and bring awareness that grounded each of the collaborator's mental space.

An appropriate environment will guide the process of making the shared mental model between the users and here is where visual representation can play a role to facilitate the environment in performing the collaborative CCA. According to Senge & Jaworski (2011), by externalizing the mental spaces that can continually grow, evolve and develop, the users are able to have a shared mental model. It is where the visualization can play an important role to facilitate the environment in which Collaborative-CCA are performed. Visualization can bring together the collective ideas of collaborating team members. The important aspect of visualizations is that they can externalized these ideas and thoughts from the internal mental space of individual team members. Being an explicit and structural, the visual representation is able to guide and clarify the process of collaborative CCA with a clearer picture – with that, the users have the opportunity to deepen their own knowledge and conscious in producing the valuable output.

According to Kolfschoten & Brazier (2012), when a team collaborates, its members often go through goal oriented cognitive processes with roughly three phases which are *divergence* to gather information, *sharing* of the information, and then *convergence* to bring the information into a shared understanding. At the individual level, the mental space can work together with the external representations, and together they form a joint cognitive system, where some of the internal load is distributed externally on the visualization (Zhang & Norman, 1994). At the group

level, the situation can be more complex because there will be negotiation that happens at two levels: individual-to-individual and individual-to-visualisation. It is in this sense that collaborative visualizations need to support the divergence-convergence process in a meaningful way.

On a larger context, cognitive overload during the transition from the divergence to the convergence phase is due to the evolving information from the emergence of information and knowledge uncertainties. From the real organization's verification, it causes effects such as unsure of where to park new information, interchangeable and redundant points of information, too much information to handle and missing the previous points. Since mental model is the cognitive patterning for the users, the moment we improve our effectiveness in the environment, we have made a step of improved correspondence between the mental model and the evolving of information during the cognitive induction (Hodgson, 2009). Thus, by having a representation space that is capable of structuring and constructing the evolvement of information emergence, we facilitate better correspondence between the collaborator's mental model and the evolving content of collaborative CCA.

As a summary, it is essential to create an environment where mental spaces will continually centralize, guide, grow and develop. Hence, the research found the significance of the representation space to play that role. Especially in the collaborative settings where a shared mental model is playing the most important role and be the essence for a better Collaborative-CCA performance.

5.2.2 Information Space

An information space is an environment, source, domain, place or area of containment from which a body of information originates. According to (Sedig et al. 2012a), while research has recently been focusing on the human side of the user-visualization discourse, there is not much attention given to conceptualize the information side. Many researchers in visualization science refer to the body of information with which users engage in discourse as 'information space'. However, aside from sporadic contributions, not much effort has been placed on the development of general models,

theories or characterizations of information space within visualization literature. The source of massive, messy, diverse and ever changing volumes of information (Thomas & Cook 2005) can be many (Bates, 2005), and they can be from concrete realms, existing within a physical space (e.g. oceans), or abstract (e.g. stock markets), originating from a non-tangible and non-perceptible sources.

When speaking about information space, it is meant by to all components that can reside within it. These components can be in terms of conceptual entities, properties, structures, processes, relationships or temporal properties. From an organization's perspectives, information can be derived from internal sources—for example, produced by knowledge workers in the finance department or R&D division- and if this information is properly analysed and understood it can provide the organization with knowledge of the organization's strengths or weaknesses. In addition, information can also be derived from sources external to the organization (e.g. trend data of users' demand for competitors' products and services), and this information, when properly presented, can provide the organization with insight of opportunities or threats. The types of data captured is increasingly complicated and complex, and in the context of enterprises, the analysis of the data is down to people with expertise in knowledge management, business intelligence, and more recently big data.

There is a general trend in organizations to gain a deeper understanding of information coming from internal and external sources. It is essential for organizations to respond and act accordingly to emergent information. It is in this sense that teams need to frequently assimilate new emergent data to make decisions that are more time and context-sensitive so as to minimize any external threats, maximise opportunities, leverage of strengths, and overcome weaknesses. In addition, during the cognitive process new data will be produced in terms of ideas, suggestions and possibilities. These outcomes of the cognitive process can become new knowledge to the management team and have the potential to spark another new formative and summative knowledge construction, a process often called innovation (Hoque & Baer, 2014). Any external tool should be able to do both, to assimilate new incoming data and to be able to integrate new ideas from the analytical team working with the data.

Basically, from the previous chapter, the research has identified two types of emergence elements from this perspective: i) the input - information to feed the cognitive process and ii) the output - new interpretation from the cognitive process that is evolving during the performance of collaborative CCA. Thus, the visualization must consider these two type of information emergence during the solution development later.

5.2.3 Representation Space

The representation space is the interface that brings together the information space and people's mental space. Through the use of visual representations, it externalises elements of the two other spaces to facilitate the process of Collaborative-CCA. It is in this sense that the design of the representation space influences how a user perceives the information space and also how each collaborator's mental space is shared to help undertake collaborative activities. The representation space gives information and thoughts a tangible, visible form at the interface level and, by doing so, makes them accessible to people, especially for group work tasks. Given the limitations of visual representations and interface technologies, it is seldom possible to encode all the elements of an information space into one single representation, and as such partial views of the partiality of the data are provided. Such limitations will make meeting the multi-faceted CCA needs challenging. In a way user-responsive representations allow people to rely on the context and content of the evolving information

While the representation space is a component that contains the abstract and detailed information but without the interactive component, content in the form of visual representation is simply a static image with exploration constraints. Thus, the interactive elements play an important role in the cycle of forming expectations and insights. However, (Sedig et al. 2013) have done a comprehensive job to fulfil the needs for interaction space design for CCA. While interactive design has been taken care of constructive visual interaction where actions are performed and consequent reactions occur, it is an additional layer added to visualizations. The visualization field is still lacking a representation space that is applicable for dynamic information feeds.

Real time visualizations will emerge as a new set of elements come in as time transpires. Therefore we intend to focus more on a representation space design for the collaborative CCA. Furthermore, in a larger context, we hope the outcomes from both studies will complement each other to form a comprehensive guideline to consult the visualization design for the collaborative CCA.

At a glance, we found that the determination approach is pinning the underlying thinking of the current visual representation design. The information being represented in a passive and determined manner to the users (e.g power point, prezi and Keynote) locks collaborative CCA into a course that disregards any input other than information provided by the computer space. Pre-selected set of information and visualization to support users viewing static without interactivities with or annotate the information is obviously irrelevant for discourse. Whereas, from the collaborative perspective, we found the study by Isenberg et al. (2011) and Hodgson (2009) have shed some light on the importance of engagement between the users' mental model and the information environment. According to Isenberg, the higher level of interactivity between users and information environment leads to a higher level of engagement of social interaction, from viewing, interacting/exploring towards sharing and creating. Thus, the visual design should be capable of actively uploading and sharing the input from the users during the collaborative CCA. However, based on classic space-time matrix settings and five applications of real world example for collaborative scenario as we can see - the collaborative visualization is more in solving complicated instead of complex challenges. Interactivity capabilities in these studies are relevant for creating new visualization and prediction from the database but clearly inadequate to handle the evolving information from emergence of uncertainties as discussed in the previous section 2.5.2.

Moreover, we do realize that the visualization-computational based is rooted from computer science field, hence computer supported concerns more on the accuracy and integrity of the data, thus limits any new input elements without integrity to be in the representation space. It is in contrast with the needs for collaborative CCA. Since the Collaborative-CCA process is developing the solution, it diverges new interpretations of ideas, suggestions and abstractions that might be wrong and far

from integrity to be gathered, shared and brainstormed. At this point, accuracy and integrity might cut off the possibility of improvisation and deviation and the chance to adapt new input. At some extent, the dynamic visual representation makes it more flexible for the new input elements. However, they are still in need of some improvement on the elements to enhance the flexibility and dynamism of the representation space in handling Collaborative-CCA.

5.2.4 The Reflection Summary

After the visualization reflection, the research found that in handling the Collaborative-CCA, the representation space of visualization is not only meant to represent the complexities of information. Moreover, based on the set of Collaborative-CCA challenges, the research also found the essential role of the representation space supports the users' mental space by a) centralizing the mental space, b). Provide the guidance for the convergence, and c) fostering the knowledge growth as summarized in Table 5.1.

Table 5.1 The Roles of Representation Space

The Collaborative-CCA Challenges	**The Role of Representation Space**
a) Different mental model in achieving the shared goal.	**Centralize mental space.** The selection of visual structure rationales from the understanding of context of use and group fit design in order to externalize and centralize the different mental space.
b) The lack of understanding the importance of convergence	**Provide the guidance for convergence** To guide on convergence, it is important to let the users understand the main value of Collaborative-CCA and capable to draw, guide and show the overall interconnection between different elements during the collaboration
c) The evolvement of emergent information	**Foster the dynamic growth** The dynamic of visual representation to guide the construction and growth of the emergent of information evolvement.

For each of the representation roles identified above, Table 5.2 is the research plan to propose the feasible solution outcomes. Each of the row represents the kernel theories that will help to define the outcomes and design theories as the outcomes of the solution.

Table 5.2 The Feasible solution for the representation roles.

The representation roles	**Kernel theories (help to define the outcomes)**	**Design theories (The outcomes)**
The overall to handle information complexities and support the users' mental space.	a. The convergence aspect of the collaboration. b. Distributed Cognition Theory c. Epistemic artefact	Foundation for Convergence of Visual Representation Design (Converge VRD) to support interactivity between representation space and mental space
1. Centralize mental space	a. KV field – KV Framework b. IV field – visual structure via the diagram, tools and techniques.	Converge-VRD Design Principle 1: KV-IV synergy to create dynamic shared understanding
2. Provide the guidance for the convergence	a. Overview concept b. General System Theory c. Forming the cycle of formation	Converge-VRD Design Principle 2: Systemic view approach for visual structure synthesizing.
3. Foster the dynamic of information growth	a. An active interactivity loops b. Second Order Cybernetics c. Modifiablity and Perceived Finishedness	Converge-VRD Design Principle 3: An open ended interactivity approach for organising and structuring

The rest of this chapter will describe the process to develop each of the roles according to the DSRM phases. Firstly, the research will explain the process to develop the Convergence of Visual Representation Design (Converge-VRD) as a foundation of the design theory. Then the research will explain the process to develop each of the design principles based on the representation roles. During the explanation, we will describe why and how each of the the kernel theories might help to advise the solution. Then, the prescription for the design principles as the prime outcomes for this study will be described accordingly.

5.3 DEVELOP THE CONVERGENCE VISUAL REPRESENTATION DESIGN (CONVERGE-VRD).

From the previous reflection, the research now understand the visual representation space is not only meant to represent the complexities of information, hence it must be able to represent the information complexities in a way can support the users' mental space. Thus, in providing the visual design solution to facilitate this kind of role, it must align the representation space to centralize, synthesize and organize the growth of information complexities while facilitating the Collaborative-CCA process. By

having those capabilities, the representation space is able to externalize, centralize, guide, grow and develop users' mental spaces during Collaborative-CCA. More over, with dynamism, it can be able to facilitate the organization in handling their information emergence towards Collaborative-CCA knowledge construction.

5.3.1 The Theories for Visual Design (VRD) Development

By highlighting the capabilities above as essential for the visual representation design (VRD), we need some theories to substantiate the design foundation. Therefore, this research has considered three kernel theories: (i) Convergence Aspects of the Collaboration, (ii) Distributed Cognition Theory, and (iii) Epistemic Artefact as the foundation of Converge-VRD. Each will be explained in the paragraph below.

a The Convergence Aspects of the Collaboration.

This research considers the convergence aspect as a starting point to the initial characterization in developing VRD. The adaptation from convergence aspects is used as a principle for the VRD development. Kolfschoten & Brazier (2012) have identified three key aspects to converge in the collaboration, which are: i) creating a shared understanding, (ii) abstraction/summarization, and (iii) creating overviews and structure / organization in a set of contributions by identifying relations.

Before we further describe each of the convergence principles in details, there is a need to understand how the convergence aspect can help this design solution to handle the challenges appropriately. Since, the reflection shows the importance of the visual representation design to manage and guide the users' mental model, then the Converge-VRD should be able to handle the collaboration activities and its cognitive process while performing Collaborative-CCA. For this situation, the convergence aspect is capable of directing a collaboration into one focal point. By physically having a convergence aspect as a one stop centre, it can help to centralize the different mental model among the users in terms of physical participation and the cognitive process of divergence. For physical participation, the convergence aspect can attract, guide and centralized the attention and discussion among the users while the process

take place. Meanwhile, for the cognitive of divergence process, the convergence aspect can show, relate and structure the process for information divergence to converge into a meaningful and higher level of abstraction during the collaborative-CCA process.

b Distributed Cognition Theory

According to Hutchins (2000), distributed cognition is a theory that addresses knowledge that lies not only within the individual but also in the individual's social and physical environment (external) and is a framework that involves the coordination between individuals, artifacts and the environment. It is rooted from the Vygotsky's Activity theory and Constructivist approach that emphasize the process of constructing knowledge through the use of mediated artefact. Through an experiment, Kirsh & Maglio (1994) have simplified the concept of the distributed cognition theory using the example of playing tetris. Playing the tetris needs the user's mental model to rotate the blocks in order to form a full line of the bricks. While playing tetris, to fit the new block to the current construction, the user's mental must rotate the block accordingly - 90°, 180°, 270°, 360 or back to 0°. Performing physical rotation on the screen games helps the user's mental model perform the rotation faster. Thus, they conclude that the external environment (game screen and the rotation activities) guide the internal mental representation (user's mental model).

The idea of using Distributed Cognition as a framework for investigating human-computer systems will not be a new idea to many HCI and visualization researchers, where attempts have been made to Distributed Cognition to inform research (Liu et al. 2008; Liu & Stasko, 2010; Kirsh, 2006). (Liu et al. 2008) and (Liu & Stasko, 2010) explain how the concept of interactive coupling of distributed cognition between the internal mental models and visualization in model-based reasoning is capable of controlling the overflow of user's mental models that lack precise information and have limited human working memory. The interaction between internal mental models with visualization could result in a clearer reasoning process. According to Sedig & Parsons (2013), to implement complex cognitive activities, users will often do a combination of integrative and dynamic between

internal and external representations to assist the complex information process. Thus, by taking into account on the distribution of cognitive theory, the concept does not only offload the computation memory but is also capable of integration to shape and alter the cognitive process. Their study also shows that the key tenet of interactivities between the mental model and visualization must consider on the coordination aspect instead of control. This is because the concept of interactive coupling considers reciprocal between human (internal mental representation) and visualization (external representation). Changes in the internal mental representation will lead to changes in the external representation and vice versa. Links and interdependence between the two elements are significant as interactive coupling affects one another. Therefore, it is important to take into account the dynamic relationship, involvement of reciprocal action and harmonious interaction in shaping the VRD.

In this thesis, we argue that the distributed cognition framework can be used to substantiate the foundation of VRD. The study found that interactive coupling of the distributed cognition theory is capable of demonstrating the importance of a stronger interactivity between the users' mental model and visual representation space.

c Epistemic Artifacts

Despite numerous new tools, mechanisms and techniques introduced withinthe IV field, without understanding why and how human interpret, communicate and reason with the visualization will limit our ability to design the techniques (Hundhausen, 2014). As mentioned before, VRD should play a role to facilitate the physical activities and cognitive processes during Collaborative-CCA. Thus, the VRD development must consider to let the visual representation space play a role as an epistemic artefact.

Epistemic artifact is the tool to aid human in processing information better and faster (Norman 2013; Kirsh & Maglio 1994); they extend or supplement human cognition. Being an epistemic artefact is essential when the activities and domain is related to the higher level of thinking and activities. This is because, human deploys general and high level strategies to operate on information space when dealing with

CCA. The manner in which human performs interactivity with visualization to engage in complex activities are often non-linear and do not follow a pre-determined path. In spite of following the programme such as the simple structured tasks (e.g fill in the blanks, documentation and filing procedures), a human performs an epistemic cycle to carry out information-based complex cognitive activities. According to Parsons et al. (2015), interactivity is the quality of interaction in reference to human characteristics and expectation. Since the research is clearly concern more about human centered than technology centered, then the visualization is not concerned about the efficiency of the visualization response time, rather focus more about how the interactivity is affecting the Collaborative-CCA process. Moreover, (Sedig et al. 2014) mentioned that the interactivity that takes place between a user and visualization can be categorized into two levels: micro and macro. Interaction at the micro level emerges from the structural elements of individual interactions, as for interaction at the macro level emerges from the combination of sequencing and aggregating properties and relationship of interaction as the user performs an activity. Thus, the lower level activities influence the performance of the higher complex cognitive process and vice versa.

When dealing with the complexity of information, interactivity is the key component of a carrier to support the exploration of data items with multi efforts (Lima, 2011) and provide the value of reasoning for higher level knowledge (Liu et al. 2008). (Liang et al. 2010) argue that the facilitation for complex cognitive activities is not only through reducing the cognitive load, otherwise providing the users to coordinate and manage the information during the activities appropriately. Due to the Collaborative-CCA, the information needed will be massive, real time, from different sources and multi level of depth. Thus, the epistemic artifact in this sense will play a role to organize and manage the information in a way the users can coordinate and use it properly. In this sense, the structuring of the information content is important to guide the process of organizing and placing the information in the representation space in a way that users can coordinate and manage to handle it appropriately.

In this manner, Sedig & Parsons (2013) have done more comprehensive work about the interactivity within the epistemic cycle. The CCA are segregated into four

main hierarchy levels: activities, tasks, action and events (as mentioned in chapter 2). Action is the higher level of events, tasks is the higher level of action and activities is the higher level of tasks. The users will perform any kind of epistemic actions in the external environment to help them alter it and, as a result, transform and support their own cognitive function to gradually achieve the overall goals of the activity. Therefore, at higher levels, emergent properties occur as a result of the combination of phenomena at lower levels. Thus, the structure of an epistemic artefact must be able to support the lower to the higher level of activities.

5.3.2 Theorizing for Convergence Visual Design (Converge-VRD) Development

The research proposed the combination of convergence aspects, distributed cognition and epistemic artefact as the foundation for Converge VRD as illustrated in Figure 5.3. By considering the convergence aspect as the foundation for Converge-VRD, the research intended to ensure the design for visual representation space being a focal point to coordinate different mental spaces among the users. In this sense, visualization representation spaces are also epistemic artefacts, whose primary function is to enhance the information processing by presenting data in a way that can be assimilated more effectively by the users' mental space perceptual and cognitive faculties (Brey, 2005). Then, through the distributed cognition of interactive coupling between visulization representation and mental space, the users think with and through the aid of external artefacts - that is, there is an interplay between the human mind and what is presented externally to it. The couple that exists between the mind and visualisation should be one of reciprocity, with the mind acting upon the representations and these responding back. (Liu et al. 2008; Liu & Stasko, 2010) have described how the concept of interactive coupling between the mental space and representation space is capable of controling the overflow of the mental space of users, who lack precise information processing and have limited working memory. The coupling could result into a clearer cognitive process.

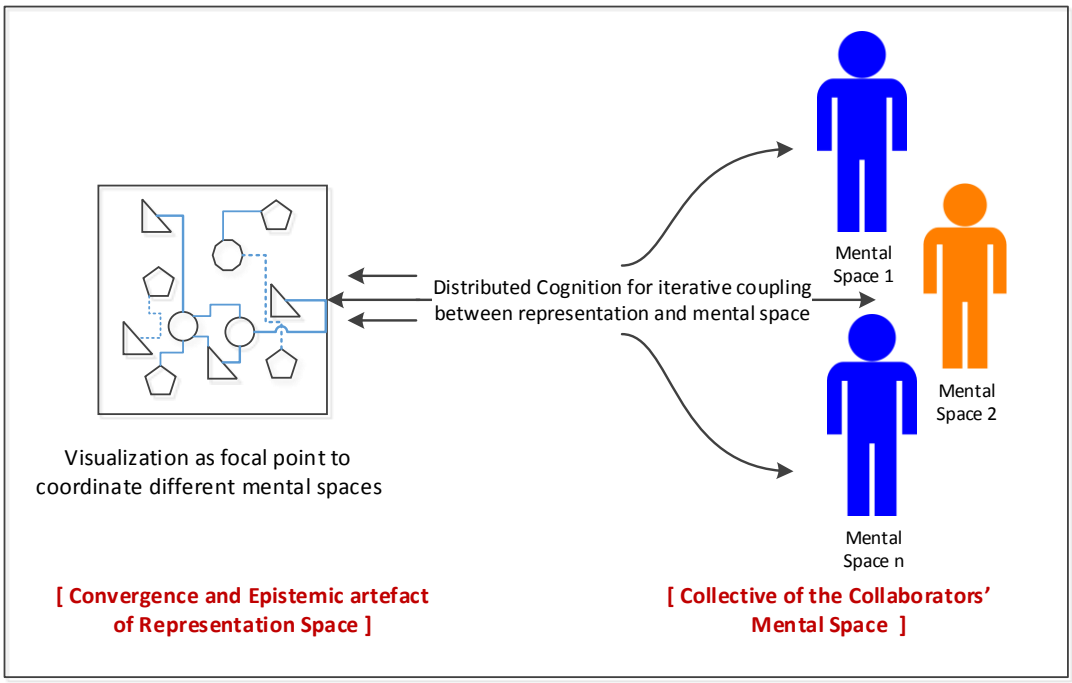


Figure 5.3 The Foundation of Converge-VRD to Develop Visual Representation Space Through Convergence and Epistemic Artifact as a Focal Point to Coordinate Different Mental Spaces during the Collaborative-CCA Process'

By taking into account the distribution cognition and epistemic artefact, it will help produce visual representations that do not only offload the computation memory but also are capable of shaping and altering cognitive processes. Their research also shows that a key tenet of cognitive activities is that of coordination instead of control, especially when multiple analysts (in this case, the users) are involved. There should be a partnership in the interactive coupling between the mental and representation spaces. For this reason, this research present three aspects of convergence with epistemic approaches and considering an interactive coupling through distributed cognition theory to substantiate the VRD development in which we simplified the term as Converge-VRD. Therefore, the thesis will further develop each of the convergence aspects as the visualization design principles in handling the challenges in a more specific, detail and relevant way. Each of the principle will be further described by the title of:

- Converge-VRD Principle 1 – KV-IV synergy to create Dynamic Shared Understanding

- Converge-VRD Principle 2 – Systemic approach for Visual Structure Synthesizing
- Converge-VRD Principle 3 – Open Ended Interactivity for Organizing and Structuring

5.4 CONVERGE-VRD PRINCIPLE 1 - CREATING DYNAMIC SHARED UNDERSTANDING

The research proposes the first principle for Converge-VRD which is to create a dynamic shared understanding by having a flexible visual design based on the context of use and group fit design. This is because convergence involves the movement from diversity to uniformity. According to Kolfschoten & Brazier (2012), to create a shared understanding entails creating a shared meaning of language symbols and labels, resolving asymmetry of information, and resolving differences in collaboration directions. Users can achieve shared understanding when they come to a common understanding of concepts and words that are related to the activity at hand. In addition, when it comes to collaborative situations, the goals may differ from individual to individual, but at some point they should all have one single common goal to ensure that it can satisfy the interests of every person (Comi & Eppler, 2010).

One current problem that surrounds our discussion of the goal setting as a shared understanding is that we are often uncertain about what the potential elements are that come into play, as the goal often needs to be formulated dynamically based on the activities of Collaborative-CCA and the goals for a complex condition is context dependent, time sensitive and thus emergent. That is why we propose the goals for collaborative CCA should be open ended. The user's goals and information needs might potentially play a role as the goal to create a shared understanding that can evolve over time (Albers 2004, 2008, 2005). Since the goals are open-ended, the shared understanding formed through convergence should be dynamically changed according to its context of use. The dynamic visual design must consider items identified from the activities surrounding the users' mental space or in other words, the collaborator's context and activity as rationales for the visual design development.

Thus, the research proposes the first principle for Converge-VRD as the dynamic of visual design based on the context of use and group fit design.

From the discussion above, to create a dynamic shared understanding based on the context of use and group fit design, the research must consider two points in developing the Converge-VRD. The first one is the visual design must be able to be a one-point reference as a common uniformity to create a shared understanding between the diversity of mental spaces. The second point is we need to bear in mind that the visual design as a one-point reference must be dynamically changed according to its context of use and group-fit conditon. While investigating the solution for the dynamic one point references in the current visualization fields, we found the synergies between the fields of Knowledge Visualization (KV) and Information Visualization (IV) have a potential to help in seeking for the solution.

5.4.1 Theories for Creating Dynamic Shared Understanding

IV and KV share the same basic purpose of using visualization as tools to support human cognitive system (users/stakeholders/recipients). The difference is that, IV uses visualization to amplify cognition in promoting human efficiency in well-defined human tasks (Schneiderman, 1996; Amar & Stasko, 2005; Sedig & Parsons, 2013) while KV uses visualization as a communication mediator to build an understanding, insight and make decisions (Burkhard & Eppler, 2004; Bresciani, 2008; Bertschi, 2009; Masud et. al, 2010).

IV is traditionally viewed as computer-supported, interactive, visual representations of non-physically, abstract based data for human support to understand and analyse large, complex data sets. The objective for IV is basically to handle overloaded information. IV typically helps to improve information retrieval and access, and generally optimizes through the visual representation for large data sets (Shneiderman 1996; Chi, 2002; Card, et. al, 1999; Ware, 2012). On the other hand, KV views visualization as a communication tool to foster knowledge directly and indirectly. As the knowledge needed to be seen, visual representation might surface misunderstanding in a complex insight, experience or prediction. For an example,

Diagrammatic Reasoning becomes a thinking tool by an individual or a group to tackle a difficult problem. KV finds visualization is used not only for representations of data but also serves as a catalyst for a collaboration process (Eppler 2011a, 2011b) and serves the purpose of constructing and communicating useful knowledge (Bertschi et al. 2011; Eppler & Bresciani 2013; Mengis 2007a, 2007b). Because visualization is very much related to the business community in Knowledge Management, it has received more attention due to their interest to create, integrate and apply knowledge particularly in the management context (Eppler 2011a; Tergan, 2005; Canas et al. 2005). The field took the lesson learnt from architect (Burkhard 2005). KV also views visual representation as a Boundary Object that serves the purpose to share, transform and maintain a common identity across sites. Even if visual representation could have different meanings in different social or professional context, their structure is common enough to more than one professional community to make them a recognizable means of translation. (Eppler 2011) and (Comi & Eppler 2011)

Although both the IV and KV fields share the same purpose in using visualization as a tool to support the human cognitive system, IV concentrates more on how to support human using the technologies while KV is more on understanding the context of which the visualization tools may support. Because the IV historical roots are in scientific reasoning, computer graphics and algorithmic optimization, the research has typically focused on supporting expert users in executing complex data exploration and analysis tasks as efficiently and effectively as possible. As for interactive visual representation, IV concerns more on tasks, techniques, interactivities, visual forms and structures (Infovis, 2012). As they concentrate more on technologies and apparatus, IV typically presents little context or guidance beyond what is directly presented within the data (Moere & Purchase 2011). In contrast, (Berscthi et. al, 2011) emphasizes that KV improves communication on the interaction around cognitive process, in particular. It has the ability to fabricate the necessary understanding of the process that emphasize the visualization process-driven concept. KV aims to understand how the sender's intended meaning can be transferred in such a way that it is not distorted in the recipient's perception. In other words, it is important firstly to understand the context of communication, followed by visual

representation (message) to be encoded according to the context. This process allows for an effective and efficient communication. Therefore, by looking from the Knowledge Visualization perspectives, Bertschi (2009) mentioned that the context (medium) is more important compared to content (message)

While IV and KV share the same basic purpose of using visualization as a tool to support the human cognitive system, but nevertheless they are tackling different angles and having different focal domain. IV utilizes visualization tools to amplify cognition especially in handling overloaded information, thus the focal domain is more towards mediation and technologies, while KV utilizes visual representation as communication tools to foster knowledge and thus the focal domain is more on understanding the context of which the visualization tools may support. At a glance, the synergy approach between KV and IV has a great potential to create a dynamic shared understanding for Converge-VRD. Therefore, by explaining the concept of KV and IV will clarify how they can further complement each other during the synergy perspectives.

a Knowledge Visualization (KV)

Knowledge visualization (KV) was introduced in 2004 and has been well accepted since then. Burkhard & Eppler (2004) define KV as "*the use of visual representations to improve the transfer and creation of knowledge between at least two persons*". Through an understanding of users, knowledge transfer and perception should be better, more efficient, and generate further aggregate knowledge. With a focus on business and management, KV designates all graphic means that can be used to construct and convey complex insights, experiences, attitudes, values, expectations, perspectives, opinions and predictions to enable someone to re-construct, remember and apply these insights correctly. KV aims at understanding the functions, augmenting knowledge creation, and identifying the cognitive and organization needs of users from the perspective of cognitive, perception and social communication, and as such can supply some insights for us to determine how to design visualizations.

Burkhard (2004; 2005a, 2005b) and Eppler & Burkhard (2005, 2007) have introduced a Knowledge Visualization Framework (KVF) as a foundation for KV. It is concerned with issues and challenges that arise from the users' perspectives during a visualization facilitation and use. This framework proposes that for visualizations to enable knowledge transfer and creation, they should have concerns from four perspectives: (i) function type, (ii) knowledge type, (iii) recipient type and (iv) visualization type as shown in Figure 5.4. The function type is basically from emotional and cognitive functions such as coordination, attention, recall, motivation, elaboration dan new insight (CARMEN-acronym). The knowledge type takes in all type of knowledge – know-what, know-how, know-why, know-where and know-who. For the recipient type, as mentioned earlier, this study is to investigate the specific needs from the perspectives of cognitive, perception and communication among the users in the group. From the visualization type, since KV has the limitation on the visualization type, the research intended to extend the selection of the visualization type and tools perspective from IV later.

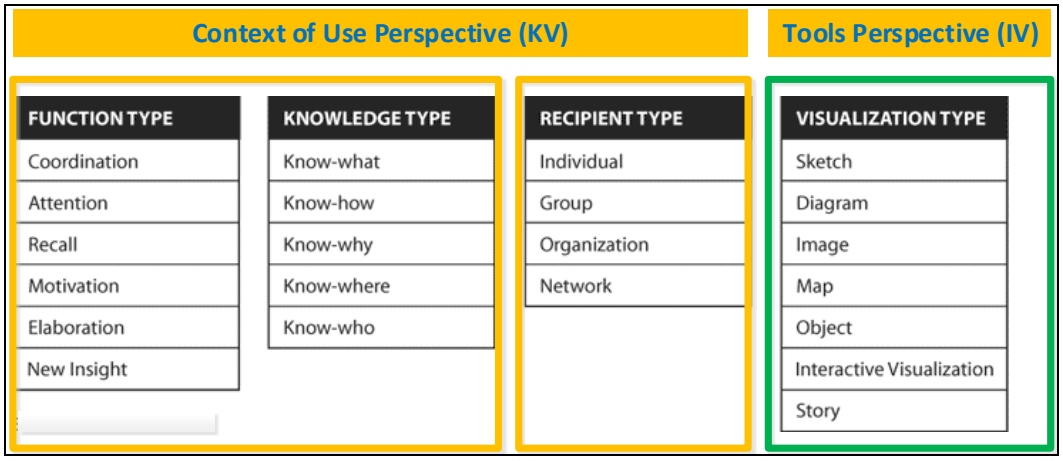


Figure 5.4 Knowledge Visualization Framework (source; Burkhard, 2006)

Somehow, KVF has enlightened the way to understand the context of design (function, knowledge and recipient type). However, the KVF is general for various domains and situations. Since this research is focusing on the activity and collaborative settings, KVF alone is inadequate to guide the understanding for it. The lesson we learned from challenge identification in chapter 4 highlighted the importance to understand the pattern of incoming issue for complex context of use, meaning, the activities, its domain and goal are among the first element to be

identified. Through this, we can focus the facilitation on activitiy-based, hence function and knowledge type must be identified according to the activity. Furthermore, for this particular research, since we concentrate on the collaborative, the recipient type in KVF has been specified as the group. The differences between their roles, level of knowledge, cognitive styles, communication and social skills will contribute to the collaboration process. However, since this research is based on the cognitive, the context of use should focus on the cognitive styles as to let them gain awareness about their mental differences.

From the discussion above, the research proposes to follow the guidelines from KVF as a foundation to understand the context of use. On top of that, due to the collaborative-CCA condition, we amend the KVF according to the action-group condition, the first element to be identified being the activity-domain and its goal. Then the function and knowledge type must be according to the identified activity. Further than that, the recipient type only focusing on the group and the individual cognitive style within the group are needed to bring awareness about their mental differences. The amendment of KVF according to the activity's context of use and group fit design is illustrated in Figure 5.5.

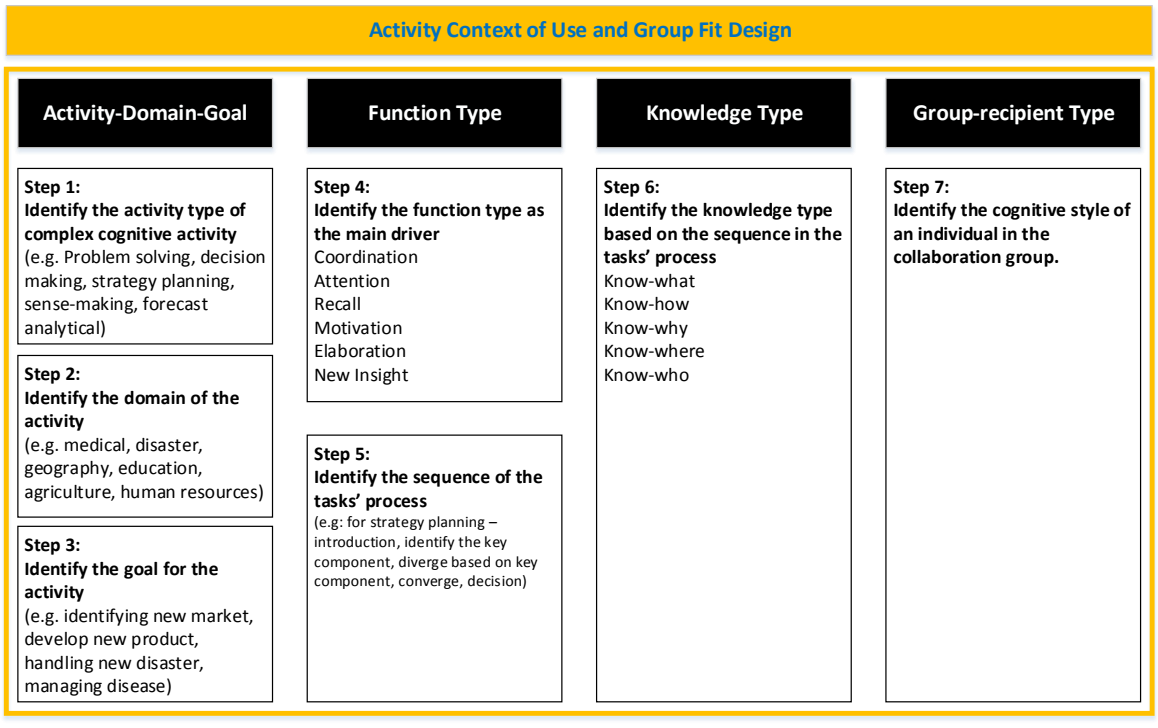


Figure 5.5 Activity Context of Use and Group Fit Design

b Information Visualization (IV)

IV utilizes visualization tools to amplify cognition especially when there is an information overloaded; as such, the focal domain is more towards mediation and technologies and until recently focuses on single users of IV is producing a huge amount of visual representation diagrams, tools and techniques. According to Moere and Purchase (2011), IV tools refer to a broad range of digital tools and resources that allow users to view, analyze, manipulate, and/or communicate complex information, such as historical, spatial, and statistical data. Information visualization tools range from freely available tools that produce simple visual representations of small data sets to proprietary tools that can manipulate complex data. Moreover, IV techniques cover a wide spectrum of application fields, but mostly consist of expert-level solutions that solve well-defined and specialized tasks.

According to Ya'acob et al (2015), in designing the visualization based on complex cognitive processes, the study of Kalfschoten & Brazier (2012), Amar & Stasko (2005), Ziemkiewicz (2010) and Albers (2004) explains that the visual structure is the critical element as the foundation ofthe semantic relationship in representating visualization and solving complex cognition activities. Previous studies have shown how visual structure was used to reduce the cognitive load (Mayer & Moreno 2003). (Mengis 2007a) justifies that the visual structure facilitates experts and decision makers and gives benefit towards knowledge integration. Earlier than that, the study of Albers (2004) has developed a user-recognizable structure that is capable of mapping between mental models with the current situation. Meanwhile, Kalfschoten & Brazier (2012) propose a pre-structure framework as a basic convergence of knowledge in the complex collaboration process and Vitiello & Kalawsky (2012) justify that the interactive visual structure is capable of collecting systemic insight in emergent behaviours. The underlying theories about visual structure are mostly based on the Cognitive Load Theory and the Cognitive Architecture (Sweller & Merrienboer 2005; Paas et al. 2003; Paas et al. 2004). They enlighten the capabilities of the visual structure in supporting the cognitive architecture to reduce extraneous load. It is also highlights the essential of pre-structure framework as a basis for knowledge understanding and furthermore, the dual

coding theory emphasizes the picture superiority effect. In this situation, the knowledge is stored in the memory as visual and words, therefore a person has twice as much memory and is more likely to remember.

The research has realized that IV tools and methods have been advanced more than the visual structure. With the combination of visual representation, content, interaction and organization (Adnan et al. 2005), the IV tools and methods can be completely used to handle certain domains and functions. However, due to the CCA needs, the research intend to utilize and manipulate the foundation of IV diagram, tools and methods – which is visual structure. Furthermore, the research proposes to concentrate on the contextual of visual structure for the dynamic representation space design solution. According to Flensburg (2009), the complex knowledge needed to be communicated is divided into two elements – context and content. Context is about how to process the activities and content is about how the information is being contructed. By guiding on the context, content will then dynamically evolve according to the emergence of information during the Collaborative-CCA process. Moreover, (Eppler et al. 2011b) highlight the structure and guidance is required to frame and focus thoughts during the process of sharing, creating and integrating information across epistemic boundaries. Therefore, our study seeks an importance of visual structure as the contextual of representation space to centralize, guide and extend the mental space dynamically during the process of Collaborative-CCA. Nevertheless, it is difficult to select and provide a specific visual structure that is suitable for all cognitive processes since the CCA condition is uncertain and context dependent. For that reason, as a prerequisite, it is important to understand the context usage to determine the suitable and appropriate visual structure as the contextual for the representation space design.

5.4.2 Theorizing Synergistic KV-IV Towards Creating Dynamic Shared Understanding

As the synergy process begins to move from the epistemic perspective that brings the needs for the context of use to a more realistic and pragmatic perspective in designing, thus the appropriate approach is necessary to consider the capabilities to integrate the

epistemic perspective into a pragmatic implementation. A number of studies have mentioned the benefit of synergies between KV and IV (Tergan et al. 2005; Cañas et al. 2005; Keller & Tergan, 2005; Bertschi et al. 2011; Burkhard, 2004, 2005a; Keller & Grimm, 2005; Meyer, 2009). It is because KV and IV share the same basic purpose of using visualization as a tool to support human cognition and reasoning, but do so from different angles and perspectives. KV with its focal domain being more on understanding the context usage of which visualization tools may support while on the other hand, IV has been utilized and developed visualization diagrams, tools and methods to amplify cognition in various domains and applications. There is a natural complementarity between KV and IV, and this has potential to produce the visual structure basis as a dynamic one point of reference to create a shared understanding between the diversities of collaborative-CCA process as illustrated in Figure 5.6 .

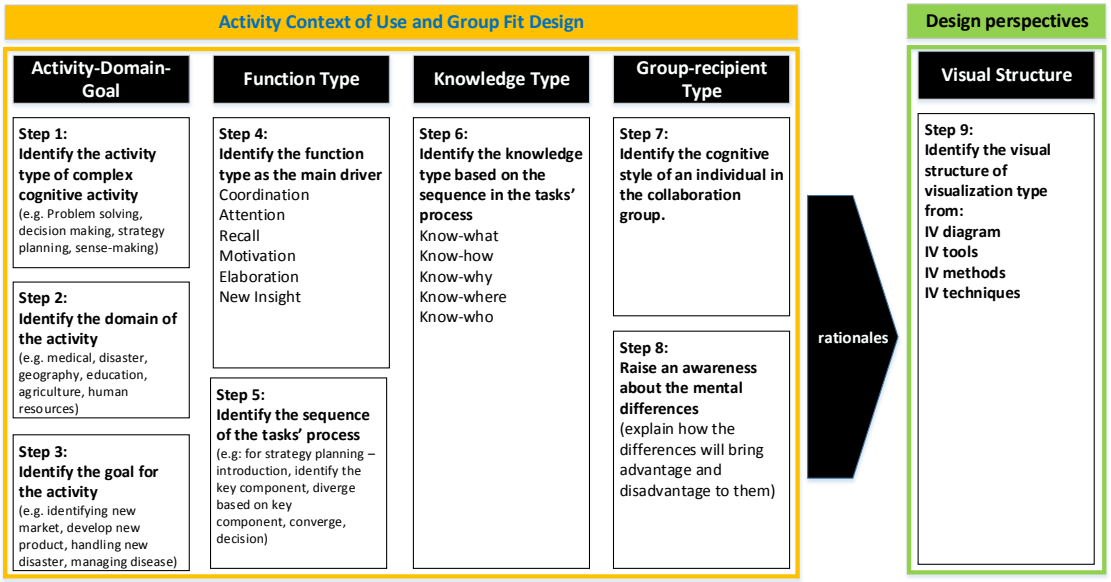


Figure 5.6 The Synergistic KV-IV towards creating shared understanding

Context of use is important for visual representation design. We theorize a synergistic KV-IV as they can complement each other and provide foundations to inform the design of Collaborative-CCA (Liu et al. 2008; Liedtka & Ogilvie, 2011). We propose that one can leverage KV for its understanding of activity context and group fit design and IV for its foundations on visual structure design. According to Liedtka & Ogilvie (2011), the synergistic approach seems to have potential in connecting and getting the synergies between two elements of different thought

perspectives. The synergy seeks to bring an understanding of the context of use from the KVF extension that is both abstract and uncertain as a rationale to determine the concept of the visual structure design that is more practical in IV. Through this synergy, two benefits are derived: (a) the extension of KVF as the guidelines to capture the context of use for the Collaborative-CCA process and (b) rationales for the contextual design of visual structure.

a The Extension of KVF as the Guidelines to Capture the Context of Use for Collaborative-CCA Process

KV can supplement IV to inform the design of Collaborative-CCA. KV has utilized visual representations as communication tools to foster knowledge, with its focal domain being more on understanding the context of which visualization tools may be used and supported. By focusing on the Collaborative-CCA process, the guidelines must be capable of informing the activity-group based condition, therefore, the research has extended the KVF towards the activity context of use and group fit design by embedding the element of activity-domain-goal, and the identification of function and knowledge types must be based on the activity. Furthermore, the guidelines concentrate only on the group recipient type since the research is focusing on collaborative settings. Thus, the individual cognitive style and the differences awareness have been highlighted as important in the group recipient type in the guidelines. The overview of the activity context of use and group fit design as the guidelines is highlighted in yellow framing as in Figure 5.6.

b Rationales for Contextual Design of Visual Structure

The understanding onthe context of use and group fit design above (a) is essential as a rationale to identify the match and suitability of the visual structure.Through this rationale, the design of the visual structure is dynamic and depending on the activity context of use and group fit design. As a result, we propose the visual structure as the contextual representation space to centralize, extend and share mental models in order to manage the content. Following the KVF extension as the guidelines, the visual structure will be matched and selected as the contextual design accordingly.

5.5 CONVERGE-VRD PRINCIPLE 2 – SYSTEMIC VISUAL STRUCTURE SYNTHESIZING

Synthesizing is combining different elements to form a coherent whole. As discussed earlier, the users perform lower level actions on the visualization space as a synthetic process so as to support their cognitive reasoning and analytical processes. The approach is to consider processes at a higher level as constructive and emergent, instead of reductive, and this will make it possible that processes at lower levels to underpin the development of more sophisticated emergent patterns at higher levels. In the context of visual design for Collaborative-CCA, we will need to provide tools and structures to support the synthetic approach. To do this, we need to understand better the synthetic process, in both individuals and groups. The synthesis process is essential because, as stated earlier, the visualizations must play a role to inter-relate the elements structure that are often not able to display the entire system into one single view (Yaacob et al. 2015).

It has been suggested that an important approach to support synthesis is that of summarization and abstraction to eliminate redundancy, similarity and overlap (Kalfschoten & Brazier, 2012). Summarization can be achieved by capturing the essence of information with fewer information elements and representing it with fewer information elements. Through summarization methods, we will select only unique information, then merge similar contributions to keep only the essential, and finally select an instance of similar pieces of information to represent multiple instances. Abstracting information can be performed by creating higher level concepts that encompass relevant information from the original set. The purpose of abstraction is to make the content more cognitively manageable by allowing people to pay attention to relevant information and to ignore other details. Abstraction can be done by generalizing a set of similar objects regarded to be a specific generic type / object. It can also be attained by aggregating the relationships between objects in a hierarchical manner. When dealing with visualizations, abstraction and summarization techniques can be automatic and carried out by users. As of yet, there is little research about summarization and abstraction techniques in complex visualizations, and as such, these techniques will need to be developed and tested.

5.5.1 Theories for Visual Structure Synthesizing

In order to support summarization and abstraction for visual structure synthesizing, the research considers three kernel theories as the foundation. Each of the theories will be described in details in the next paragraph: i) General System Theory, ii) Overview concept, ii) Cycle of expectation formation.

a Overview Concept

The concept of summarization and abstraction is closely related to understand the interconnection and provide the big picture in the sense of holism. Hence, from the visualization-computational based perspective (for instance – information visualization, visual analytics, knowledge visualization and data visualization), an overview concept is the key element that should consider the systemic view for big data interfaces. Overview is the key element in the classical visual information-seeking mantra - O*verview first, zoom and filter then details on demand* by Schneiderman (1996). However, the context of meaning for overview is incomplete for the systemic point of view. According to Hornbaek and Hertzum (2011), the meanings and uses of the notion of overview from an information visualization research mainly discuss a technical sense of systemic, in which an overview is a display that shrinks an information space and shows information about it at a coarse level of granularity. Although this mantra suggests the importance of a user's initial high-level view of the data in framing further analysis, it seems to capture only the modest parts of overview. In particular, their emphasis on getting an overview first and preferably pre-attentively is at odds with descriptions of overviewing as actively created throughout a task.

By having the synthesis through summarization and abstraction means the users should be able to understand the reality and overall situation. They should be clear of the main driver, capable of identifying the key points and see the interconnections between various perspectives, understand the interconnection between various elements and finally, give them readiness to handle any emergence of ideas, information or tasks during Collaborative-CCA. Therefore, we attempt to extend the

technical function of an overview to suffice the demonstration of the systemic view. Thus, we extend an overview concept towards the systemic view.

b General System Theory

Since the inevitable of the systemic view in the current visualization-computational base is rooted from the theory of analytical reductionism. It states that the system is a 'sum of its parts' and the account system can be broken down into different individual accounts. That theory is applicable for a complicated system but clearly a mismatch for complex matters. Therefore it is important to implement the theory that can provide the overview in the sense of systemic. The systemic concept has been mentioned by Aristotle 2000 years ago when he explained the significant holism is something over and above its parts and not just the sum of them all (Corning 2002). According to Mengis (2007a) and Eppler et al. (2004), the concept of system thinking is rooted from the General System Theory (GST). GST had been introduced by Von Bertalanffy in the 1930s and under system science, GST evolved to System Thinking around 1950 to the current date. Within that, Checkland, Ackoff and Senge are among the key persons that contributed to the significance of GST in handling complex challenges, especially for the organization and management perspectives.

GST approaches the problem like a supply chain. Rather that reacting to individual parts that arise, GST will understand the underlying interconnection between various elements within a system – looks for patterns over time and seek for the root case. One of the famous metaphors to describe GST is an Iceberg Model (Gerber, 2012). There are four levels of GST from the Iceberg Model, namely: i). Events as the reaction on what just happened, ii). Pattern and trends to anticipate what trends been there over time, iii). Underlying structure is the design that influenced the pattern to understand the interconnection between parts and iv). Mental model as the platform to transform the assumptions, beliefs and values that people hold about the system as illustrated in Figure 5.7.

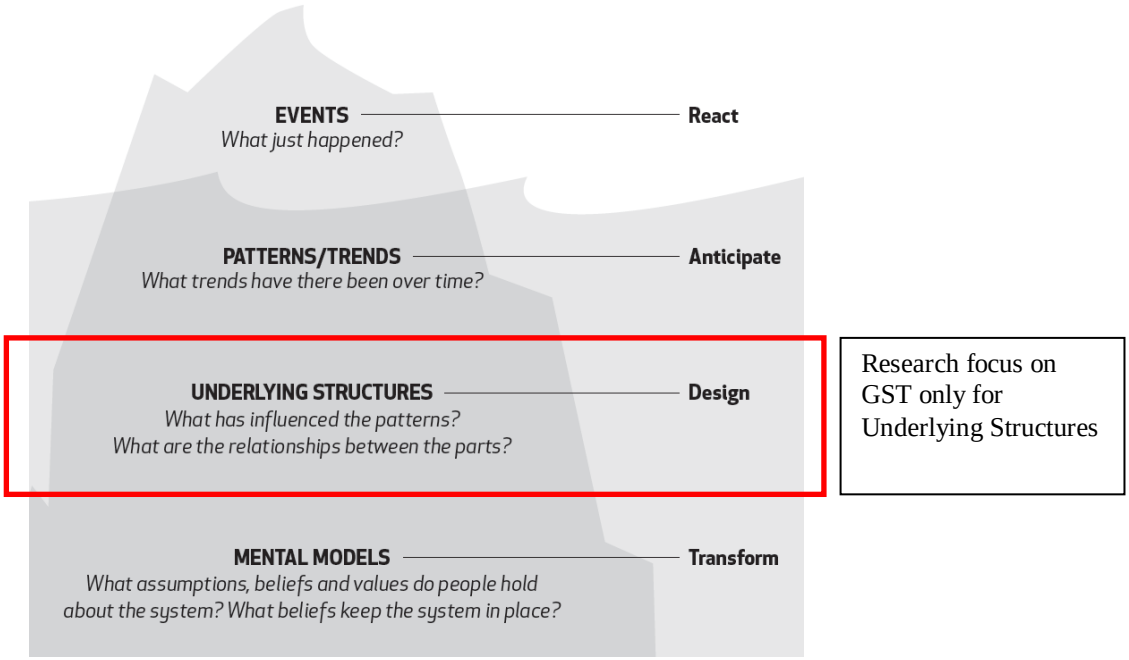


Figure 5.7 Iceberg Model as Metaphor for General System Thinking

(source: Gerber, 2012)

Because of the large extent of the GST level to be examined, we propose to concentrate the systemic view for visual representation on level three – underlying structures. Our study seeks an importance of the underlying structure of the Iceberg metaphor to clarify the interconnectedness between elements of information to represent system as a whole. Based on Mengis (2007b) and Ziemkiewicz & Kosara (2010), we are aware that presenting visualization for the systemic view must at least contain the interconnection between elements and also between the higher levels of information (for instance: abstraction, key points and perspectives) and lower level information (details). So far, literature review in the visualization-computational field finds that the visual representation design focus is sufficient in presenting data part by part for lower level details. Therefore, to achieve a higher level of information, we argue to have a higher level structure to complement a lower level of object data in forming the cycle of expectation.

c Forming the Cycle of Expectation

For higher level thinking (analysis, synthesis and create), Ziemkiewicz (2010) describes the process as how people interpret the visualization as 'the cycle of forming expectation' process as illustrated in Figure 5.8. Basically, to interpret visualization, the process is between making hypotheses at a higher level structure and later confirming the hypotheses.The confirmation can be done through checking the relevant details at a lower level. Object data will recur iteratively until the users are satisfied and get the full understanding of the problem or the phenomena. The details for the cycle of forming expectation is as below:

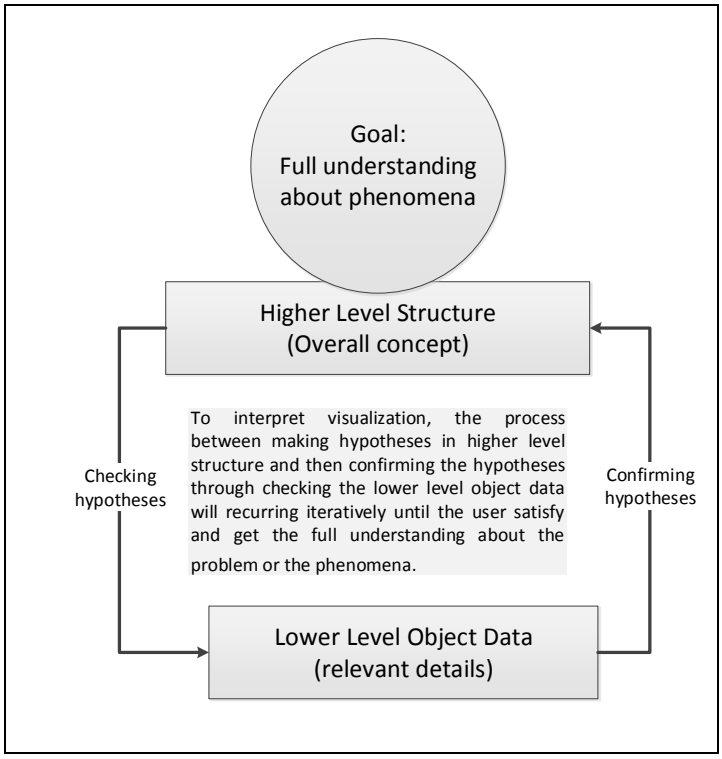


Figure 5.8 The cycle of forming expectation
(source: Ziemkiewicz 2010, illustrated by writer)

- A human viewing visualization first sees just a collection of shape. Low level perception produces descriptions of objects and some sense of the overall gist.

- Simple visual grouping can give rise to perceptions of clusters and other simple organizational properties. At this point visual structure become important.

- The viewer may use visual decoding to extract object-level infomation, but only for a limited number of marks (due to the limitation of working memories)

- At a higher level, the viewer is beginning to get a sense of the structure of the visualization. This happens initially through simple simulations of the dynamics acting on the image. The field vaguely organized visual marks become a collection of objects acting on one another, through forces such as attraction, repulsion, support and connection.

- Once these dynamics have been perceived, the viewer can metaphorically transform these simulations info inferences about data relationship. For example, an apparent attraction between two marks suggests to the viewer that the objects they represent have something in common, while an apparent repulsion may suggest that those objects have opposing goals. At this point, knowledge of the semantic domain of the data may also come into play to constrain or suggest certain metaphorical interpretations, as may the user's own preconceptions and expectations.

- Once such inferences start being generated, the user checks them by reference to individual data points, which is when the efficiency and accuracy of variable decoding become an important part of the process.

- This object-level data is interpreted in context, however. The viewer will already be forming hypotheses about the data based on the visual structure and their understanding of possible data relationships will be powerfully constrained by the mental model they have begun to form.

- The prosess of using visualization then, is a cycle of forming expectations about structure, forming hypotheses based on that structure and checking to see if low-level data conforms to those hypotheses.

- The results of those checks will be incorporated into the ongoing mental model of the data, which will then lead to new hypotheses and expectations.

- Structure and data interact constantly in the user's attempt to understand a problem or phenomenon and the strength of good visualization lies in its ability to model its data in a way that supports this interaction meaningfully.

From the cycle of formation, Ziemkiewicz (2010) emphasizes the importance of a higher level of visual structure to fill the gap in understanding how people communicate and reason with visual information, especially for complex cognitive processes. Meanwhile, IV from the overview concern basically operates at a lower level of abstraction and focuses mainly on raw data and information. A study from Schneiderman (1996), Card et al (1999) and Bertin (1986) were basically operated at a lower level of abstraction and focus mainly on the raw data/information. Therefore, to achieve a higher level of abstraction, (Ziemkiewicz & Kosara, 2011a) and (Ziemkiewicz & Kosara, 2009; 2011) suggest to have higher level structure of IV to complement the lower level of object data in forming the cycle of expectation. They argue that the encoding of visualization structure which is similar to how human structure information in their cognitive thinking would be useful in understanding the complex cognitive processes.

5.5.2 Theorizing Synthesis Visual Structure

We propose the systemic approach as a basis for the visual representation structure to synthesize the information complexities during the Collaborative-CCA process. The concept of systemic is closely related to understand the interconnection and provide the big picture in the sense of holism. Hence, the research theorizes the synthesis visual structure by extending the overview concept towards the systemic view. Then using GST, the research proposed the systemic view by embedding the underlying structure (layer 3 of the iceberg) to underpin the concept of the synthesis visual structure. Moreover, the cycle of formation will help to strengthen the needs for higher level and lower level of multiview visual structure as to support synthesis as higher level thinking.

The visual structure synthesizing claims 3 important element within this principle; (i) higher level visual structure, (ii) lower level visual structure, and (iii) the interconnection between higher and lower level visual structure. In consequences with the previous principle design, we have been highlighting the importance of the context of use as rationales for the visual structure design. Therefore, this section will continually explain how the whole step in the context of use will play a role to rationalize the higher level visual structure and steps 4-6 are essential for detailing rationales in a lower level visual structure as shown in Figure 5.9.

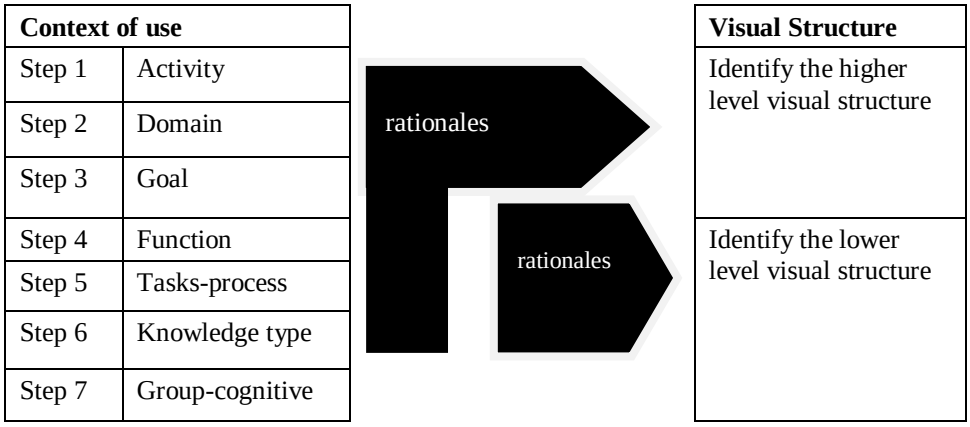


Figure 5.9 Context of use as the rationale for visual structure

a Higher Level Visual Structure

In terms of the higher levels, Ziemkiewicz and colleagues (Ziemkiewicz & Kosara 2008, 2009) have argued that the encoding of the visualization structure should be similar to how people structure information and this would be useful in helping them carry out complex activities. In addition, they highlight the use of metaphors to frame higher level visual structures and, by doing so, allow the abstract overviews. It is important that the overviews will allow users to make hypotheses about the information space at a higher level and enable them to confirm (or reject) these hypotheses at a lower level. Thus, it is clearly understood that the context of use for the macro level is essential as the rationales for this part (steps 1-3 from the context of use). As many cycles would need to be carried out, the structure need to be fluid, and fluidity of visualizations may not be easy to have when metaphors alone are used. There is a need to go beyond the metaphors. This is because, the importance of the

metaphor has been highlighted as higher level visual structures to allow for the abstraction overviews for the visual representation. We argue that lack of metaphor alone as higher level visual structures to handle complexities and provide a systemic structures. Thus, we propose multiple-view properties as a synthesis visual structure to complement the concept of higher level information with the lower details to generate the systemic view of visual representation design. In order to create multiple-view properties of the visual structure, the context of use from the perspective details is also important to indicate the elements needed in the multiple-view properties. Thus, we suggest step 4 of the tasks-processes, step 5 of function and step 6 of knowledge needed is important to rationalize multiple-view properties for the higher level visual structure. The combination of these will help to form a more comprehensive visual structure as to guide the higher level of abstraction during the collaborative-CCA process.

b Lower Level Visual Structure

Much of the literature has focused on the lower level representations. Thus, the research can easily choose, apply and combine the current visual structure as the lower level to present and guide the detailed information. The selection of these can be rationalized from the context of use on the detail parts in which are step 4, 5 and 6. According to Paas et al (2003), to reduce and manage the cognitive load, the overwhelming of the details can be clustered and categorized according to the key components. The selection of the key components can be according to the priority business and activity goal in the context of use – either based from function, tasks or knowledge in the context of use.

c Interconnection Between Higher and Lower Level Visual Structure

Furthermore, according to Mengis (2007a) and Ziemkiewicz & Kosara (2010), contextual visual design must at least show the interconnection between higher levels of the information space (abstraction, key points, and perspectives) and lower levels (concrete details). It is important to handle the analyticial and synthetical process and furthermore the divergence to the convergence phase. This is because the users

develop abstractions of the higher levels by accessing and manipulating the lower level details. Therefore, the relationship between these lower and higher elements is important to facilitate the reasoning process. To support the process, the cycle of formation can strengthen the main relationship between the higher level and lower level of visual structures.

We propose the organization of visual structure from an assumption of going from divergence to convergence - from lower level details to the higher level of abstraction. The lower part is to encourage discussion of lower details, and is meant to help the understanding of the 'state of the art' of each of the elements, perspectives, or departments. The upper level has been placed to guide the analysis process towards the synthesis of the cognitive process so that convergence of ideas and ideas can take place over time. As a whole, the users are able to view the higher and lower level at the same time. They can view, relate and refer to the details during the reasoning for higher level abstraction.

Moreover, through the organization of the visual structure, our emphasis is on guiding the users to discuss details according to any of their particular needs. The whole structure design of the visual representation will act as explicit guidelines to be shared across several mental models so that there would be shared understanding among the users. By knowing what to do through the visual structure, it makes the process more focused on relevant elements. Nevertheless, since the research is about the complex domain, the interconnection between elements is not limited between the higher and lower level visual structures, hence the relationship can also be formed either between the elements in the same key component, between different key components or lower level details. As the summary, the interconnection between higher and lower level structures to form visual structure synthesizing in the systemic approach is illustrated in Figure 5.10.

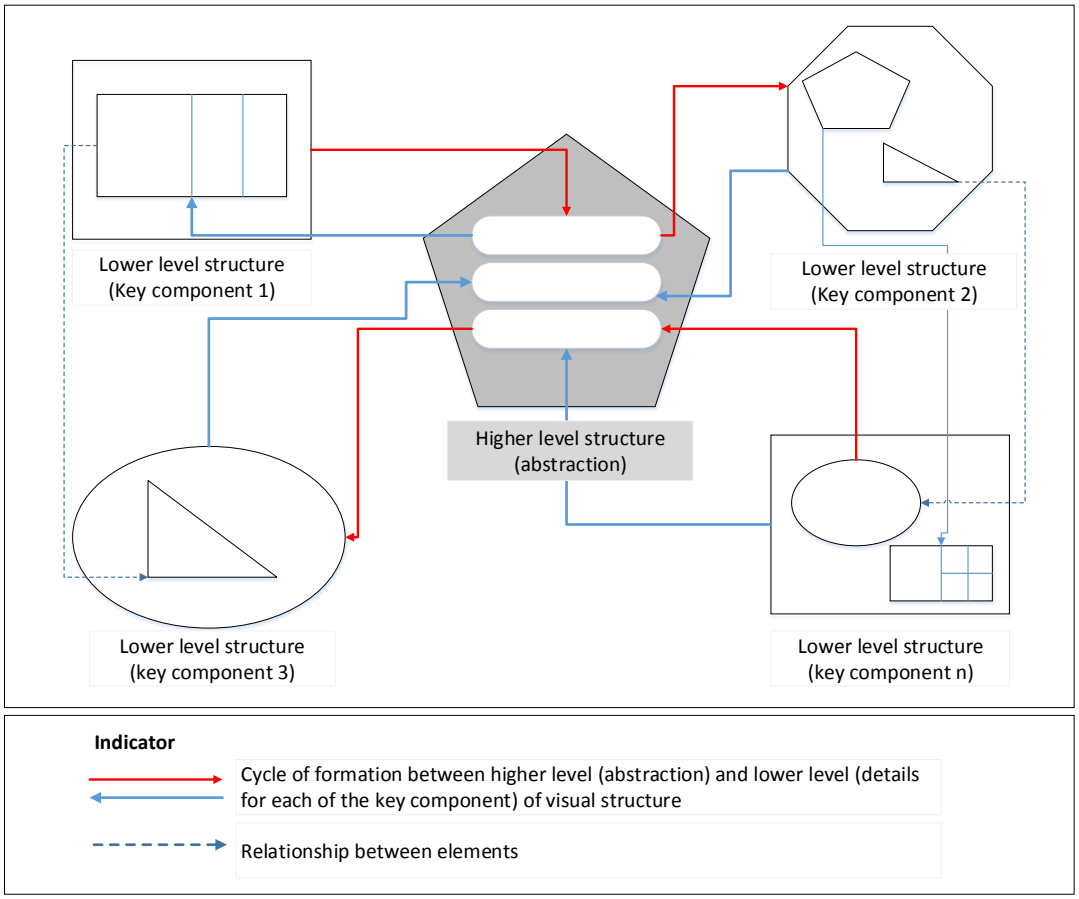


Figure 5.10 Systemic Approach for Visual Structure Synthesizing

5.6 CONVERGE-VRD PRINCIPLE 3 - OPEN ENDED ORGANIZING AND STRUCTURING

An emergent behaviour or property can appear when a number of simple elements (e.g., entities, agents, and data) operate in an environment, forming more complex behaviours as a collective. To form structural elements, one needs to find ways to relate information, based on causality, a hierarchy, or group classification. The challenge is that in complex systems the relationships are not clear. If one type of relationship is imposed artificially the exploration may not be effective, or worse it can lead to the wrong conclusions. In addition, as new data come in, the relationships will need to be adjusted dynamically. This adjustment can change the entire structure of the visualization. There seems to be little research about dynamic structuring given new data feeds in real time during the cognitive process. Multiple views can help (Morey & Sedig, 2004), but this approach is only explored in the context of static, pre-defined visualizations, and not for cases where dynamic nature is taken into account.

Visual structure synthesizing is a contextual guidelines. It acts in a way to guide the collaborative-CCA process by coordinating an emergent of evolving content of information. Thus, the matching concept to complement the visual structure coordination is needed. Hence, the research proposes open-ended visual representation features to cater the evolving of information emergent patterns. By having these features, the users are able to construct and refine their knowledge iteratively (Burkhard, 2005b; Sedig & Parsons, 2013). Through an adjustable visual representation, even at its fundamental structural level, we hope to achieve meaningful ways to re-structure the visualizations. To achieve this, there is a need to adapt dynamic feedback loops to pin the underlying visual representation design for better interactivity between the users' mental space and information in the visual representation space. By considering multiple feedback loops, users are free to amend and put new input in the visual representation for every emerging information and ideas, in addition to the visualizations morphing itself to include new information.

During the analytical and synthetical process, the amendment is done according to current updates to make sure users are clear of what changes are taking place. An epistemic cycle is carried out between the users' mental space, internal to them, and the visual representation as an external environment. As with many cognitive activities, users will need to exert some kind jof actions to externalize their thought process and, along the way, alter the representation space to support their mental operations in a distributed manner (Sedig & Parsons, 2013). Through such process, users manage to dynamically interact between higher level mental abstractions and lower level details in the representation space, and this level of support is needed for them to develop an understanding about a problem or phenomena.

5.6.1 Theories for Open Ended Organizing and Structuring

In order to support open ended organizing and structuring, the research considered three kernel theories as the foundation. Each of the theory will be described in details during the next paragraph: i) An active interactivity loops, ii) Second Order Cybernetics Theory, iii) Perceived Finishedness and Modifiability.

a An Active Interactivity Loops

Although determined approach is practical and bring benefit for rational analysis in some domain of relative predictable, somehow it reduces the considerations of options that lead to the lost of flexibility and anticipation in complex situations. An effective decision in the 'uncontrollable world' needs an approach to deal with the missing unruly half to match between the cognitive process and the information space (Hodgson, 2009). From the visualization interactivity lenses, the emergence and constructive of the information during the process of Collaborative-CCA should be considered within three loops:

- Interactivity between the collaborator and visualization
- Interactivity between visualization itself.
- Interactivity among the users (human to human)

These will need to be developed with properties of being highly flexible and adaptable to be able to incorporate new emergent elements and patterns, which cannot easily be predicted or not known *a priori*. Second order cybernetics is an area dealing with systems in the context of feedback loops. According to Corning (2002), feedback loops are essential determinants of the nature of emergent aspects in a complex situation. There are two feedback loops: one between collaborator to visualisation and the visualisation to visualization. Each loop will affect each other, and this can add to the complexity of the analysis process. Visualizations should be designed in such a way that the changes and effects caused by each loop should be distinguishable by the users.

The process of collaborative CCA involves human-to-human communication, and this would be a third feedback loop. Some of the elements of this communication will go to the visualization, while some elements will only reside in the mental spaces. The visual representations should be able to convey the underlying users' cognition and shared ideas. In addition, according to Eppler & Burkhard (2005a; 2005b), the representations should be able to: 1) help to coordinate users in the communication process; 2) support identifying patterns, outliers and trends; 3) improve memorability, remembrance and recall; 4) motivate, inspire, energize and activate users; 5) foster

elaboration of knowledge construction in the collaboration process; and 6) support the creation of new insights by embedding details in context and showing relationships between objects. Therefore, it is important to implement the theory of second order cybernetics that can provide the dynamic feedback loop in the close interactivity between the mental space and the representation space. Due to response and stimulus from the mental and representation space in the feedback loops will affect the users' behavior and information construction during the cognitive process.

b Second Order Cybernetics

Second order cybernetics, also known as the cybernetics of cybernetics, It is more like a constructivism concept in which it investigates the construction of models for cybernetic sytems. The idea of what a person sees depends upon his or her background has become widely accepted in scientific circles. It investigates cybernetics with awareness that the investigators are part of the system. The investigator of the system is unable to understand how the system works by standing outside it because the investigators are always engaged cybernetically with the system being observed. Thas is why, they affect and are affected by it. Second order cybernetics highlights the importance of the users being investigators, who are always engaged cyberneticaly with the representation space being observed. In the case of the collaborative CCA process, when the representation space facilitates the users' mental space, they affect and are affected by it. According to Hodgson (2009), the decision maker is not simply an observer but is also a participant who cannot abdicate from personal ethical considerations and ultimate responsibility even in the face of uncertainty. It is similar to constructivism model of cybernetics system where the output from the users depends upon his or her background and contextual. Basically, cybernetics is a transdisciplinary approach in exploring a regulatory system, their structures, constraints and possibilities. Cybernetics is applicable when the representation space as a system being analyzed is involved in a closed signaling loop: that is where action by visual representation generates some changes to the users and vice versa. Since this research emphasizes more on the process of collaborative CCA, we need to be more sensible to engage the users during the communication process. Therefore, we need to extent the perspective of interaction to the perspective of

interactivity and communication in the feedback loop. This attempt on communication and interactivity values for the emergence have been greatly influenced by the works of Eppler, 2006a, 2006b; Flensburg, 2009; Eppler & Bresciani, 2013). Thus, the visual design for the representation space must convey the underlying users cognition and perception.

c Modifiability and Perceived finishedness

To enhance the flexibility and dynamism of the representation space in handling collaborative CCA, this research suggested the needs for improvement on the elements of modifiability and perceived finishedness (Hundhausen 2004) and (Bresciani et al. 2008). These elements are crucial in the collaborative process to engage and motivate users to contribute during Collaborative-CCA. Modifiability is a level of capability of visual representation to dynamically react according to any changes in the collaboration process. Modifiability encourage the participant to offer contribution, enhance the possibility of interaction and ammend the visual representation. Meanwhile perceived finishedness is a level of visual representation resembling a final and polished product. By providing the visual representation that seems incomplete might encourage the users to modify and contribute to the representation space during the collaboration process. It gives confidence to the users that the visual representation still needs improvement for perfection. In the contrary, giving the polished and perfect looks on a visual representation might hesitate the users to make any alteration or changes.

5.6.2 Theorizing an Open Ended Interactivity Approach

The research proposed an open ended as the interactivity approach for the visual representation space. As a result, the representation space can act as a mediator between the mental and information space Through this kind of approach within visual design, we hope to achieve a concise reconstruction of the information in the representation space by proposing the contextual visual design approach to support: (a) the evolving content of information growth, and (b) elements of modifiability and perceived finishedness. Each of the approach will be discussed in the next paragraph.

a The Contextual Visual Design to Support the Evolving Content of Information Growth

Visual design needs to be more dynamic (flexible, open for changes, responsive, react and amenable) to handle close interactivity between users' mental models and information in their environment. Thus, we propose the systemic view of visual structure synthesizing that has been developed in visual principle 2 which must act as the contextual of visual design to support the evolving content of information growth. From the visual structure perspective, the design must consider the representation space that acts as the mediator between the mental space and information space, and the guidelines between the users' communication and memory extension for evolving information emergence. Through the contextual visual structure design we hope to achieve a concise reconstruction of the information in the representation space. By embedding the second order cybernetics theory for active interactivity loops in the representation space, the users will be able to construct and refine their knowledge iteratively. Thus, the information as the content of the visual representation will constructively evolve according to the collaborative-CCA process. The emergence of information complexities can be added, merged and deleted according to the transition process of collaboration from divergence to convergence and up to the decision making phase.

The concept of open ended organizing and structuring is closely related to the concept of the epistemic cycle by Sedig et al (2012a) to accomplish the mental space's goal. The mental space repeatedly process and align the incoming input from the information space to accomplish the goal and come out with the cognitive output of it. According to Hoque & Baer (2014), having a feedback loop will sustain the system and act as the basis of interactivity between the mental and representation spaces, in addition to coordinating the input (from the representation space) and output throughout the information space. Thus, from the interactivity perspectives, the users will perform the actions upon the representation space and perceive its reactions as shown in Figure 5.11. An open-ended cycle is carried out between the users' mental space, which is internal to them, and the visual representation as an external environment. As with many cognitive activities, users will need to exert some kind of

actions to externalize their thought process and, along the way, alter the representation space to support their mental operations in a distributed manner (Sedig & Parsons, 2013). Through such process, users manage to dynamically interact between higher level mental abstractions and lower level details in the external representation space, and this level of support is needed for them to discover a reasoning for a problem or phenomena.

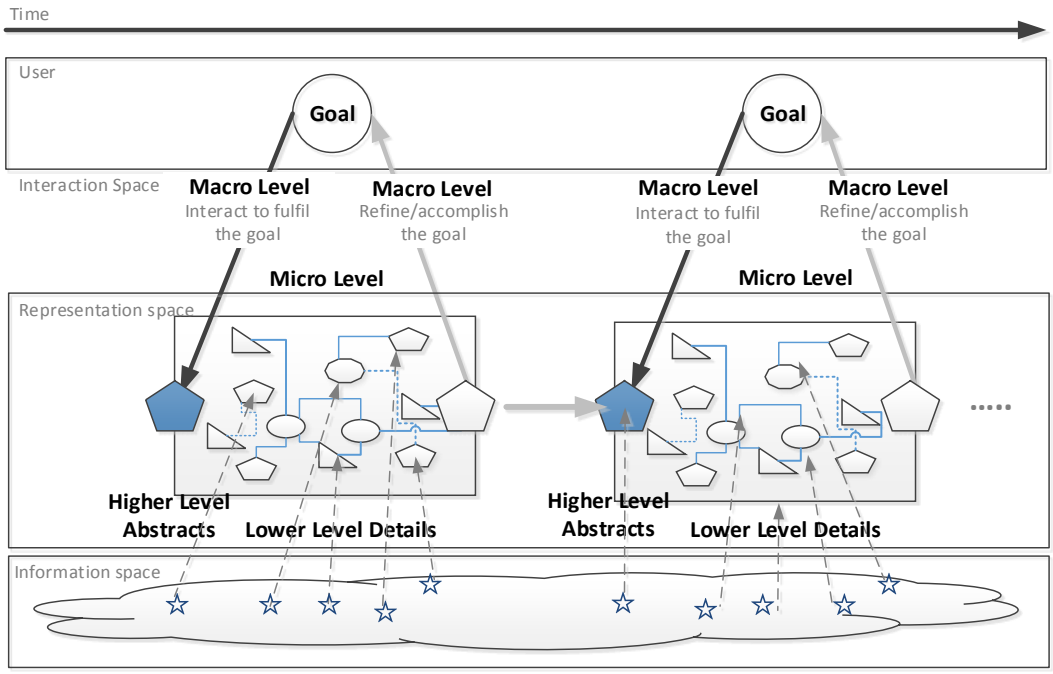


Figure 5.11 The Process of Users performing open endend action upon the representation space

b The Contextual Visual Design to Support Elements of Modifiability and Perceived Finishedness.

We bear in mind that collaboration need cooperation from multiple people, thus elements of modifiability and perceived finishedness in visual representation design might encourage and motivate the users to become more engaged and motivated during the loop of convergence process. By providing the basis of a contextual visual structure that allows modifiability for the content, an open-ended cycle provides the element of perceived finishedness to the users. They are free to amend and add a new input in the representation space. It can engage their cognitive activities together.

Important conclusions drawn from this work have shown that an open ended contextual approach towards the constructive of a visual representation space has the potential to facilitate the cognitive process, guide the users and unfold the emergence information from moments to moments during the cognitive process. We identified four benefits of open-ended visual representation space, which to act as the shared mental model to centralize the differences among the users for the evolving of emergence information, the explicit guidelines to enhance clarity, the references to extend the mental space limitation and to engage the users to contribute during the process

5.7 DISCUSSION

From an outcome perspective, Converge-VRD and its principles have become the prime artifact from the research design process. The sequence of the process and outcomes for the Converge-VRD have been summarized in the following Table 5.3.

Table 5.3 The Visual Representation Design (VRD)

Visual Representation Design (VRD) Theory and Principles		
Objective solutions (Representation roles)	**Develop the Converge-Visual Representation Design**	
	Theories (kernel theories)	**Theorizing (Design Theories)**
Overall roles-handle the information complexities and support the users' mental model.	a. Convergence aspects of the collaboration b. Distributed Cognition theory c. Epistemic artifact	**Converge-VRD as a foundation** Convergence of Visual Representation Design (Converge-VRD) as a foundation to support interactivity between representation space and mental space
Centralize mental space	a. KV Field b. IV Field	**Principle 1: KV-IV synergies to create dynamic shared understanding** a. The extension of KVF as the Guidelines to capture the context of use for Collaborative-CCA Process. b. Rationales for contextual design of visual structure
Facilitate the convergence process	a. Overview concept in IV b. General System Theory c. Cycle of expectation	**Principle 2: Visual Structure Synthesizing.** a. Lower level visual structure b. Higher level visual structure c. Interconnection between higher and lower level visual structure.
Foster the dynamic of information growth	a. An active interactivity loops b. Second Order Cybernetics c. Modifiablity and Perceived Finishedness	**Principle 3: Open Ended Interactivity approach for Visual Structure Synthesizing.** a. The contextual visual design to support evolving content of information growth. b. The contextual visual design to support elements of modifiability and perceived finishedness.

The overall reflection of the Collaborative-CCA challenges from visualization perspectives highlights the role of visual representation space is not only meant to represent complexities. Moreover, it must be able to support the users' mental space. Thus, through the foundation of convergence aspect of the collaboration, distributed cognition theory and epistemic artefact, we proposed Converge-VRD as an effective substantiate to support interactivity between the representation and mental spaces. Furthermore, the research expanded the Converge-VRD into three design principles that focused to handle the identified Collaborative-CCA challenges:

i). The Converge-VRD principle 1 – Creating a dynamic shared understanding to centralize the different mental models between users in achieving the shared goal. The theory basis for this principle is by understanding the condition of the IV and KV fields. Here, the research theorized the synergy between KV and IV to rationale the dynamic selection for visual structure. Using the advantages of KV, this research managed to have some guidelines in order to understand the context of use. Then, from the understanding of the context of use, the research used it as a rationale to identify the most suitable visual structure in the IV field as the basis to centralize the mental spaces.

ii) The Converge-VRD principle 2 – Systemic approach of visual structure synthesizing is intended to facilitate the lack of understanding about the importance of convergence. By showing an interrelated structure, the visual representation is able to draw, guide and show the overall interconnection between different elements during the convergence. Through this, the visual representation acts as the guideline that can bring awareness among the users about the importance of interconnectedness elements during the Collaborative-CCA process. The theory basis for this principle are the Overview concept, General System Theory (GST) and forming the cycle of expectation as an underlying structure of visual representation design. By theorizing the systemic approach of view between the higher level and lower level of visual structure, the research is able to show the interconnection between different elements especially on the convergence phase and the inter-relationship with divergence and decision making phases.

iii.) The Converge-VRD principle 3 – Open-ended interactivity approach for Organizing and Structuring is meant to develop the growth of information emergent evolvement. By having the dynamic visual structure, the Collaborative-CCA process can be guided during the constructive and growth of the information emergent evolvement. The theories applied in this principle are active interactivity loops, the second order cybernetics and the elements of modifiability and perceived finishedness that encourage the constructivism concept. Finally, the visual structure synthesizing that acts as the contextual visual design can support the evolving content of information growth and elements of modifiability and perceived finishedness to handle the evolving of information emergent.

5.8 CONCLUSION

This chapter holds the prime artifact for the research - Visual Representation Design. The research terms the prime artifact as Convergence of Visual Design (Converge-VRD). From visualization perspectives, it has been developed as a foundation to support the interactivity between the representation space and the mental space during the Collaborative-CCA process. Furthermore, it has three design principles to handle the identified challenges:

- Principle 1 – KV-IV synergy to create Dynamic Shared Understanding
- Principle 2 – Systemic approach for Visual Structure Synthesizing
- Principle 3 – Open Ended Interactivity for Organising and Structuring

Alignned with DSRM, the research concerned for the Converge-VRD development from two perspectives: the research design process and the outcomes. The rigorous of research design process is essential to enhance the credibility of the VRD. From the rigor cycle between the steps of design process and its knowledge base, we would like to conclude that the outcomes in developing the VRD has some basis as rationales behind it. First, we relied on phase 2 and phase 3 of DSRM as a basic guidelines to develop the VRD. The representation roles from phase 2 were based on the reflection of the Collaborative-CCA challenges (outcomes from chapter

4) from visualization perspectives. From the reflection, we were able to identify the objectives of the visual representation space hence clarify the roles for the incoming visual design VRD. Then, based on the identified roles, phase 3 developed the visual design VRD by describing theories to prescribe theorizing. Theories are the process where the research identified the suitable kernel theories to govern the problem and advise design theories. By referring to the kernel theories, the reseach theorize the design theories. It prescribe the solution by expanding, integrating and synergizing the kernel theories according to the visualization for the Collaborative-CCA process.

As a conclusion, by developing Converge-VRD as the solution for the Collaborative-CCA process, this chapter is meant to achieve the RO2 by answering the RQ2 – How should visualization design facilitate the Collaborative-CCA Process? Moreover, by following the DSRM design phase 2 and 3 to guide the research design process to develop the solution (Peffers, 2007), the research has produced the Converge-VRD as a rigor design artifact. Since VRD is the prime aim of this thesis, we will further evaluate the utility and effectiveness of VRD in chapter 6.

CHAPTER VI

VISUAL REPRESENTATION DESIGN EVALUATION

6.1 INTRODUCTION

Evaluation is the process to see how well does the artifact work. In this activity, we need to observe how well Converge-VRD as a design artifact handle the problem by comparing the evaluation objectives with observed findings. In order to do that, this objective needs the guidance from the demonstration and evaluation phases of DSRM and the qualitative approach was used during the evaluation. The focus group observation is chosen as the method to evaluate the VRD and the methodological aspects of the evaluation have been described previously in section 3.6. Within that section, the method settings of the criteria and unit of analysis evaluation, sampling and participants, tasks and settings and data management and analysis procedure have been mentioned as an optimum due to the improvement and adjustment during the iterative evaluation process. Whereas this chapter is basically to explain the implementation of the evaluation process and the findings from it.

Furthermore, the two phase of DSRM that have been executed will be explained in this chapter: (i) The demonstration of Converge-VRD and (ii) The evaluation during the experiments.

i. The demonstration phase is important to gather the users' context of use and then demonstrate the Converge-VRD as the design solution into the visual representation instrument that can be used. According to Geerts (2011), demonstration is the process to demonstrate the use of the artifact to prove that the artifact works by solving one or more instances of the problems. The most

important part during the demonstration is to explain on the 'how' knowledge to use the artifact to solve the problem. To further structure and clarify the demonstration process, we turned each of the design principles from Converge-VRD to the visual representation instruments. Using this instruments, we further demonstrate the usefulness for each of the design principles in handling Collaborative-CCA process through focus group observation. The instruments will act as the control environment during the experiment. The experiments lasted around 90-120 minutes, and during that time, the participants in the group of 4-6 people were gathered in the meeting room. Based on the CCA goal, the groups were to discuss as in a normal meeting or discussion group as long as they would refer and utilize the provided visual representation. From here, we observed and recorded the interactivity process between the users and the provided visual representation as an evidence of the usefulness.

ii. Along the way of usefulness demonstrating, the experiment is also being evaluated based on the identified criteria. The observed and recorded collaborative process has been accessed as evidence on how the principles of Converge-VRD that demonstrated through an instrument are able to effectively handle the Collaborative-CCA process.

The steps above have been important during the research design process as summarized in Figure 6.1. By relying on the foundations and methodologies from the knowledge base as stated in that figure, this chapter aim to demonstrate the usefulness of visual design VRD and access the effectiveness of it as an outcomes from this research design process.

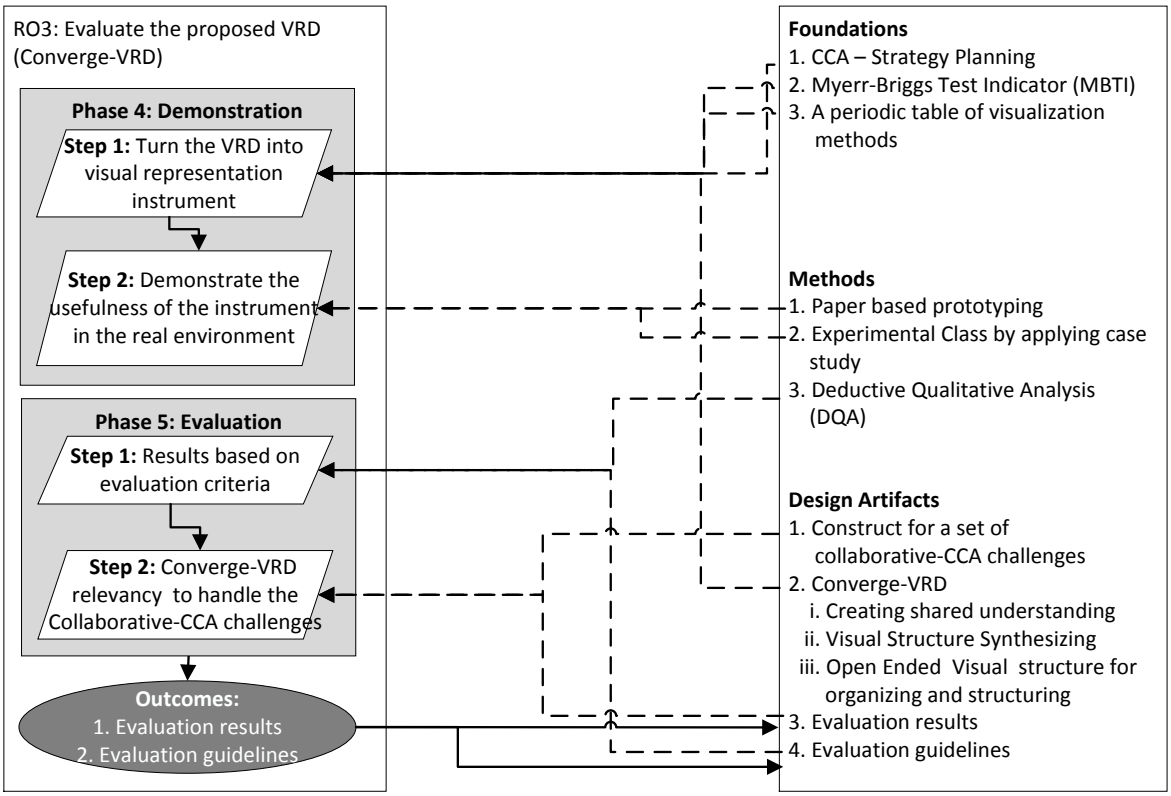


Figure 6.1 The Research Design Process for the Evaluation Activity.

The structure of this chapter also follows the above sequential steps. In section 6.2, the thesis will explain how the demonstration will turn the Converge-VRD to produce a visual representation instrument as a workable visualization. Then section 6.3 will further demonstrate the usefulness of the instruments to facilitate the collaborative-CCA process in the real settings. Section 6.4 will describe the results of the evaluation and section 6.5 will discuss how the result can further access the relevancy of the VRD. Finally, section 6.6 end the chapter by concluding the whole demonstration and evaluation phases.

6.2 THE DEMONSTRATION OF CONVERGE-VRD INTO VISUAL REPRESENTATION INSTRUMENT

This section will explain the demonstration of the Converge-VRD into a visual representation instrument by following the Converge-VRD design principles that have been summarized in Table 6.1. Based on purposeful sampling strategy and

collaborative-CCA activity-based, three (3) group of users were selected from different organization as been mentioned in section 3.8.3. The participants' selection is important for the evaluation. Due to the complex condition that is context dependent, the demonstration can only take place after the participants have been identified, then the activity to understand the activity's context of use and group fit design will be according to the selective participants. Therefore, the next section will demonstrate the Converge-VRD into the visual representation instrument based on these participants' context. Together with this, the scope limitation for the demonstration also included in its appropriate condition. The next paragraph will explain in details for each of the demonstrated activities.

Table 6.1 The summary of demonstration from Converge VRD into visual representation instruments

<table>
<tr><th>Converge VRD</th><th>The demonstration of Converge-VRD into visual representation instrument</th></tr>
<tr><td>Visual Design Principle 1 – Creating dynamic shared understanding</td><td>
Activity 1. Demonstrate the creation of dynamic shared understanding:
a.Identify the context of use by using the guidelines from KVF to capture the activity context of use and group fit design for Collaborative-CCA process.
<table>
<tr><th>Step</th><th>Guidelines</th><th>Description for context of use</th></tr>
<tr><td>Step 1</td><td>Identify the activity</td><td>Activity (*Limitation 1)</td></tr>
<tr><td>Step 2</td><td>Identify the domain</td><td>Domain</td></tr>
<tr><td>Step 3</td><td>Identify the goal</td><td>Goal</td></tr>
<tr><td>Step 4</td><td>Function type</td><td>Function</td></tr>
<tr><td>Step 5</td><td>Identify Tasks–process</td><td>Tasks-process</td></tr>
<tr><td>Step 6</td><td>Knowledge type</td><td>Knowledge type</td></tr>
<tr><td>Step 7</td><td>Group - Individual cognitive type</td><td>Group-cognitive (*Limitation 2)</td></tr>
</table>
*Limitation 1 – Focus CCA only on strategy planning.
*Limitation 2 – Identification of individual cognitive type using Myer-Briggs Test Indicator (MBTI) online.

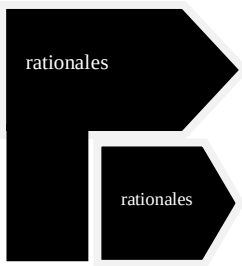
b. Rationalize the visual structure selection based on the understanding of context of use and group fit design
<table>
<tr><th colspan="2">Context of use</th></tr>
<tr><td>Step 1</td><td>Activity</td></tr>
<tr><td>Step 2</td><td>Domain</td></tr>
<tr><td>Step 3</td><td>Goal</td></tr>
<tr><td>Step 4</td><td>Function</td></tr>
<tr><td>Step 5</td><td>Tasks-process</td></tr>
<tr><td>Step 6</td><td>Knowledge type</td></tr>
<tr><td>Step 7</td><td>Group-cognitive</td></tr>
</table>
rationales
<table>
<tr><th>Visual Structure</th></tr>
<tr><td></td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>Converge VRD</th><th>The demonstration of Converge-VRD into visual representation instrument</th></tr>
<tr><td>Visual Design Principle 2 – Systemic view of visual Structure Synthesizing</td><td>
Activity 2. Demonstrate the systemic view of visual structure synthesizing
*Limitation 3 – Selection of visual structure from Periodic Table of Visualization Methods (Lengler and Eppler, 2007)

a. Identify the higher level structure:
i. The concept of abstraction and metaphor– based from step 1-3.
ii. Key components for function - based from step 4.
iii. Tasks-sequential (process) – based from step 5.
iv. Knowledge type – based from step 6.

b. Identify the lower level of visual structure
i. The selection for component of details – based from step 4-6.

c. Interconnection between higher and lower level visual structure
i. The organization from abstration (higher level) to details (lower level) – top to bottom or right to left organization of visual structure settings.

<table>
<tr><td colspan="2">Context of use</td></tr>
<tr><td>Step 1</td><td>Activity</td></tr>
<tr><td>Step 2</td><td>Domain</td></tr>
<tr><td>Step 3</td><td>Goal</td></tr>
<tr><td>Step 4</td><td>Function</td></tr>
<tr><td>Step 5</td><td>Tasks-process</td></tr>
<tr><td>Step 6</td><td>Knowledge type</td></tr>
<tr><td>Step 7</td><td>Group-cognitive</td></tr>
</table>


<table>
<tr><td>Visual Structure</td></tr>
<tr><td>Identify the higher level visual structure</td></tr>
<tr><td>Identify the lower level visual structure</td></tr>
<tr><td>*Limitation 4</td></tr>
</table>

*Limitation 4 - MBTI results are meant to bring awareness to the users about their different cognitive styles. By understanding their own and group members' cognitive style, it might help to lose some tense and bring more understanding about him/herself and also their peers during the constructive arguments in the Collaborative-CCA process
</td></tr>
<tr><td>Visual Design Principle 3 – Open ended organizing and structuring</td><td>
Activity 3. Demonstrate Open Ended Organizing and Structuring
*Limitation 5 – Paper based prototyping

a. Contextual visual design to support the evolving content of information growth and (b) elements of perceived finishedness and modifiablity

The design of visual structure systhesizing as one point center to guide the Collaborative-CCA process.
</td></tr>
</table>

6.2.1 Demonstrate the Creation of Dynamic Shared Understanding.

Based on Converge VRD principle 1, it is essential to create a shared understanding to centralize the different mental models among the users by: (a) identifying the context of use and (b) context of use as a rationale for dynamic visual structure.

a Identify the Context of Use by Using the Guidelines from KVF with an Extension for Activity-Group Fit Design.

Even though visual design principle 1 has shown some guidelines to identify the activity context of use and group fit design, the demonstration needs some practical method in a way to identify it. In the case of a complex condition, understanding the user's context means we need to identify the requirements of their business in their organization settings. By taking the examplery from Drocourt et al (2009), they show concern in understanding the context of use as a rationale for visualizations helps to make them more effective. In their study, they have relied on the real needs of glaciologists by including the context of use and how they work in the real world environment. The visualization researchers worked together with glaciologists in the real world working environment in the Greenland Waters, and found out what the glaciologists knew, what they would require more, and how they would be using visualizations to support their work practices. As a result, they proposed that simplifications of 2D glacier maps would be the most efficient and workable visual representations. The same approach to understand the context surrounding a complex system has been emphasized by Albers (2010), Still (2010) and Redish (2007). To identify the users' cognitive backgrounds, functions, business domain and knowledge needed, Still (2010) proposes using open ended, realistic scenario studies. Among the applicable methods are site visits, shadowing observations, interviews, longitudinal evaluations and natural setting experimentations.

Therefore, from the identified three groups of participants, the researcher visited their business and organization settings, made some informal talks to understand their situation and problem, and discuss the goal on what they are looking

to achieve during the focus group observation. The findings from understanding the context of use is presented from each of the step below and the summary in Table 6.3.

Step 1: For the activity, due to the scope and limitation and numerous types of CCA, each of them having more details and own field of study, the research concentrated only on strategy planning as the CCA for this particular of demonstration and evaluation. Since strategy planning is always involving multi division, roles and people in the organization, it is suitable for the collaborative case. Other than that, strategy planning is also related to other types of CCA like decision making, problem solving and sensemaking. Given that there are many activities that management teams within an organization do, to give an example to present our approach, we have chosen certain roles of the management teams in the context of developing strategies. To develop these strategies, the users must consider the acts of planning, problem solving, sense making, and finally decision making.

Step 2: For the domain, based on the same activity, the domain is based on the business area of the group participant. The domain for the three case studies is mentioned as below.

- Group 1: Agriculture investment for 18 acres of land in Nilai, Negeri Sembilan.
- Group 2: Business investment on 2500 square feet of land in Kuala Lumpur.
- Group 3: Collaborative decision strategy for public sector professionalism (Public Sector Department).

Step 3: For the goal identification, based on the activity and domain, the goals are proposed as below. Each of the goals had been verified to the group of the participants before the experiments took place.

- Group 1: Product Development Strategy.
- Group 2: Business Developement strategy.
- Group 3: Inclusiveness and Ownership Strategy for Public Sector Transfromation Programme.

Step 4: For the goal function, based on the activity, domain and goal, the function type for the main driver is about getting a new insight for the strategy. Further study of strategy planning show the importance of the four (4) key strategy components – financial, people, operational and learning and growth.

Step 5: For the tasks-process identification, based on the Collaborative-CCA process, the general tasks-strategy planning process is:

Task 1 - Introduction – understanding the goal.
Task 2 - Divergence based on the 4 key components
Task 3 - Convergence based on interconnection of the 4 key components
Task 4 - Decision making to achieve the goal.

Step 6: For the knowledge type, the demonstration for strategy found the four importance of knowledge type as below:

Knowledge what – 4 key strategy components.
Know how – the process of strategy planning tasks.
Know why – the relevancy between strategy components and process.
Know what, who and when – between abstraction and details.

Step 7: In identifying individual cognitive type for each group. Since these complex activities occur in collaborative settings, they will need to be carried out by different types of users with varied personality traits. In terms of cognitive traits, we can let them perform the Human Metric Personality Cognitive Type Test Myer-Briggs Type Indicator (MBTI) by Carl Gustav Jung and Myer-Briggs. Research from Gardner (1996) has suggested that there is sufficient reliable and valid evidence to conclude that MBTI is a reliable and valid instrument in studying relationships among managerial personalities, cognitions and behaviors. The MBTI test is able to identify the differences of personalities, cognition and behaviors. It has been widely used and is popular for applied purpose in research relating psychological type to managerial behaviors such as decision making, conflict management and leadership (Gardner & Martinko, 1996).The test has been simplified and used online. The simplified

outcomes from the initial of four letters indicate the cognitive elements as showed in Table 6.2:

Table 6.2 Indication for MBTI Test (source: Gardner and Martinko, 1996)

Initial of letter	**Indication for**
First letter	Introvert (I) vs Extrovert (E) to indicate the element of sensation
Second letter	Sensing (S) vs Intuitive (N) to indicate the element of intuition
Third letter	Logical (T) vs Feeling (F) to indicate the element of thinking
Fourth letter	Judge (J) vs perceiving (P) to indicate the element of feeling

For the above three cases, we have used the MBTI test and have been able to identify the different cognitive personalities for each of the users within a group. As we can see, each group has users with a different type of cognition. The awareness of the differences make the management group understand they have different mental models and are able to construct the solution from different angles. In addition, each user's background, roles and expertise will create a gap amongst them. This gap will need to be narrowed as the cognitive process proceeds and become centralized and collective. By understanding these point of view, it will likely help to speed up the process of narrowing the gap.

Table 6.3 The Context of Use for the Demonstration based on Participants for Focus Group Observation

Step	**Guidelines**	**Description for context of use**
Step 1	Identify the activity-of incoming issues	Strategy planning
Step 2	Identify the domain	**Group 1:**Agriculture investment for 18 acres of land in Nilai, Negeri Sembilan **Group 2:**Business investment on 2500 square feet of land in Kuala Lumpur **Group 3:**Collaborative decision strategy for public sector professionalism (Public Sector Department)
Step 3	Identify the goal	**Group 1:**Product Development Strategy **Group 2:**Business Developement strategy **Group 3:** Inclusiveness and ownership Strategy for Public Sector Transfromation Programme

Step	Guidelines	Description for context of use
Step 4	Function type	**New insight. In order to get a new insight, each of the group must reflect and understand the condition of 4 key strategy components:** 1. Financial 2. People 3. Operation 4. Learning and Development (R&D)
Step 5	Identify Tasks– process	**The Strategy Planning tasks:** 1. Introduction – understanding goal 2. Divergence based on 4 key components 3. Convergence based on interconnection of 4 key components 4. Decision making to achieve the goal.
Step 6	Knowledge type	Knowledge what – 4 key strategy components. Know how – the process of strategy planning tasks. Know why – the relevancy between strategy components and strategy process. Know what, who and when – between abstraction and details.
Step 7	Group - Individual cognitive type	**Group 1 (G1) – four (4) participants cognitive type** Participant 1 (G1P1) - INTJ Participant 2 (G1P2) - ESFP Participant 3 (G1P3) - INFP Participant 4 (G1P4) - ENFP **Group 2 (G2) – five (5) participants cognitive type** Participant 1 (G2P1) - ESTJ Participant 2 (G2P2) - NTJ Participant 3 (G2P3) – ENFP Participant 4 (G2P4) - ISFP Participant 5 (G2P5) - ISFP **Group 3 (G3) – five (5) participants cognitive type** Participant 1 (G3P1) – INTJ Participant 2 (G3P2) - INTJ Participant 3 (G3P3) – ISTJ Participant 4 (G3P4) - ESFJ Participant 5 (G3P5) - ISTJ

b Context of Use as Rationale for Dynamic Visual Structure.

As we can see from the table, the function for each of the groups is to develop a strategy for different kinds of businesses. Since their domain and environment of the business is different, the information content for each of the cases is not within the designer's control. However, the activity process to develop each strategy is similar across the three cases. The 'how' knowledge to develop a strategy has been studied

intensively by researchers in strategy planning and the larger scope of business management fields. It includes phases, steps to be taken and what elements to be considered during the strategy development in order to achieve the main driver. Therefore, by identifying the usage context, we seek further to facilitate the 'how knowledge' of the strategy activity by providing a matching visual structure. In here, we put concern in understanding the context of use as a rationale for a more effective design. By having an extension of KVF, we are able to understand the activity-group based condition in more clarity and systematically. However, the selection and design for the visual strucuture will be explaineg and described in the next step.

6.2.2 Demonstrate the Systemic Visual Structure Synthesizing.

From the previous principle, the demonstration of Converge-VRD should be capable of identifying the context of use and then using it as the rationale in developing a dynamic visual structure. In order to develop the dynamic visual structure, the demonstration must be able to select and choose the most suitable visual structure based on the previous rationales. Further than that, the selection must also consider how the selection of the visual structure is capable of externalizing and showing the inter-related elements structure for the convergence.

A modern visualization consists of computational elements. In addition, a visualization has been applied into various fields, namely advertising, management, medicine, geography and journalism. A massive of visualization tools, techniques and methods have been developed for all those fields. Due to the findings from the previous phase, we understand the function and knowledge types are focusing on strategy development of Collaborative-CCA for the organizational perspective. Thus, due to the scope and limitation for demonstration, the research focused the selection for the visual structures from the Periodic Table of Visualization Methods (please refer to Figure 6.2). It has 100 visualization structures that have been compiled from seminal articles, books and websites to enable selecting appropriate visual structures for problem solving and learning in the areas of management psychology, education, computer science, design or philosophy proposing (Lengler and Eppler, 2007). Along with that, the compilation provides structures that are fully documented, applied in

real life (especially in organizational settings), fit to represent knowledge-intensive and complex issues and applicable by non-experts. The table is organized systematically according to the complexities of the visual structure (axis-y) and the field domain (axis-x) within the domain of management and organization.

To support the synthesis process, the visual structure must be able to enable users to perform lower level actions to summarize or abstract information and take it to a higher level as a constructive and emergent activity. Thus, we have next selected the higher level and lower level visual structures from the periodic table that meet the context of use that has been identified in Table 6.3. Hence, Converge-VRD principle 2 has proposed the synthesizing as to facilitate the convergence. The important elements of synthesizing are: (i) identifying the higher level visual structure based on the rationales from steps 1-6, (ii) identifying the lower level visual structure based on the rationales from steps 4-6, and (iii) the interconnection between the higher and lower level visual structures.

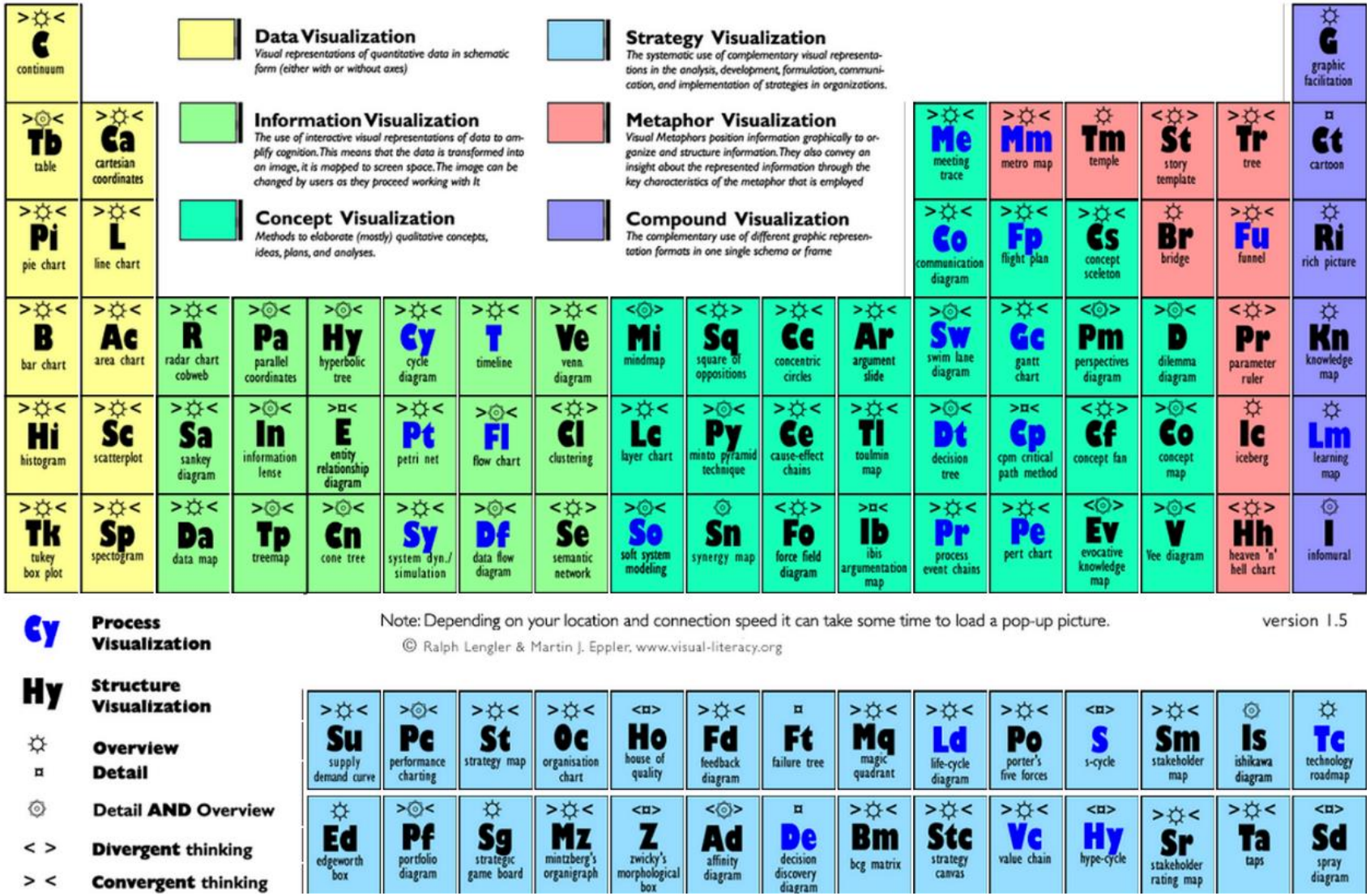


Figure 6.2 A Periodic Table of Visualization Methods
souce: Lengler and Eppler (2007)

a Identify the Higher Level Visual Structure.

To develop multiple view of properties for higher level visual structure, this demonstration has four different properties of multiple view that basically rationalize from the context of use that has been identified from the previous section as indicate in Figure 6.3.

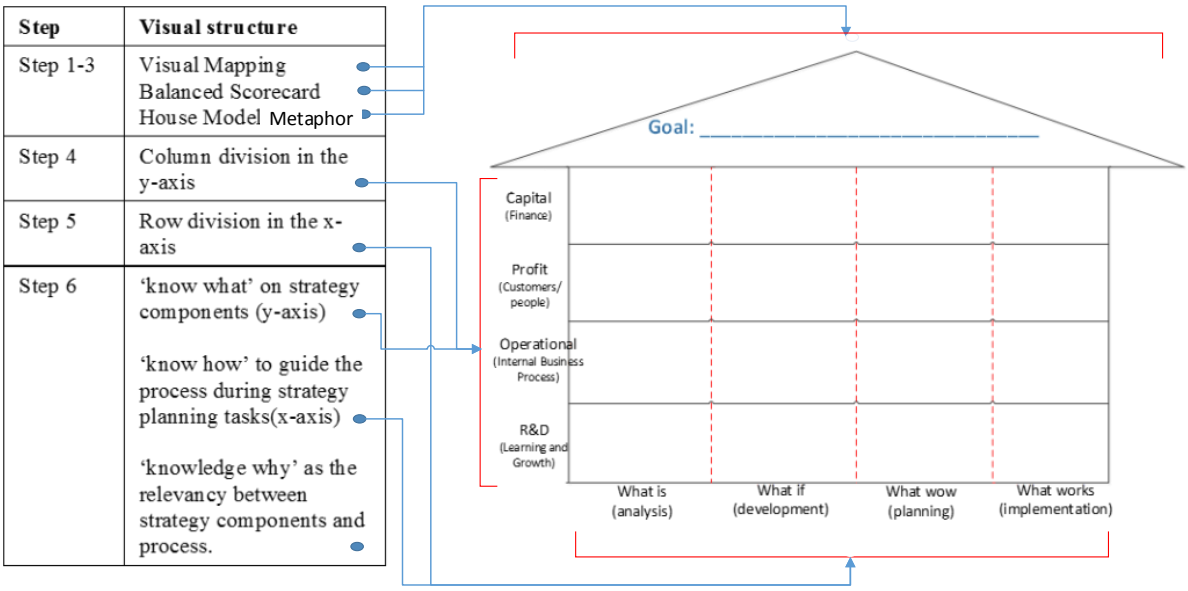


Figure 6.3 The Rationales of the Design for Higher Level Visual Structure
(used for all the three groups of focus group observation)

First, to select a higher level visual structure that has potential to facilitate strategy development (requirement from steps 1-3), the research browsed different types of visual structures for strategy visualization (at the lower part of the periodic table). From here, we have found 14 types of methods are supportive of convergent thinking ('> <' symbol to indicate convergent thinking) and overview ('O' symbol to indicate overview). From the potential 14 types of visual methods, we have then chosen the strategy map as the higher level visual structure because it has the indication for the elements to be considered during the strategy development. More importantly, by having a combination of the strategy map with the Balanced Scorecard Model by Kaplan and Norton (Pouresia et al, 2013), the visual structure embeds the elements of simplicity and is perceived commonly to be used to document the primary information when it comes to a strategic goal formulation. The Balanced

Scorecard provides a quick and comprehensive view that provide a better competetive assessment to develop the strategy. Furthermore, the House Model has been embed as the visual metaphor structure. This would allow for a more consistent and deeper understanding of visual structure to centralized mental model among the users. The house metaphor indicate it as the anchor structure for abstracting elements in the planning strategy. The discussions can go deep into certain elements, but the participants could always find an adequate abstraction by referring back to the house metaphor.

Second, to develop the strategy development abstraction component within the higher level visual structure based on requirements from step 4, the demonstration embed four key components of strategy development. The research dividing each of the elements column in the y-axis of the structure into four key components of strategy development: i) financial, ii) customer, iii) internal and iv) learning and growth. Given that the participants have some non-experts, the demonstration has simplified the jargons to make phrases familiar and easy to grasp at the beginning. For example, the term capital has been used instead of financial, profit instead of people, operational instead of internal business process and Research and Development (R&D) instead of Learning and Growth.

Third, by using the similar approach, the demonstration embed the sequential tasks (process) for CCA-strategy development in the x-axis of the visual mapping structure since the step 5 has mentioned that the focus group will go through the strategy development tasks-process as the limitation within CCA context. The research divide each of the elements row into four tasks of strategy as complex activities task-process: i) Introduction and understanding the goal – *what is*; ii) divergence to identify the potential solution – *what if*; iii) convergence to create the most effective solution – *what 'wow'*; and iv) decide the solution in the real context – *what works*. The term for task-process is also simplified to what-is, what-if, what-wow and what works for simplification and easy understanding.

Fourth, the combination of these is also provides the knowledge type that needed as mentioned in step 6. It can act as the guidelines for 'know what' on strategy

components (y-axis), ‘know how’ to guide the process during strategy planning tasks (x-axis) and ‘knowledge why’ as the relevancy between strategy components and process. As the summary, the combination of visual mapping, balance scorecard, house model metaphor and division in axis-x and-y act as the multiple view properties of higher level visual structure in order to facilitate and guide the users during the process of strategy planning in Collaborative-CCA context.

b Identify the Lower Level Visual Structure

For the synthesis process to take place, there needs to be an epistemic cycle that users would perform to check and reason from lower level details. To do this, the users must understand and get some detailed explaination about their current business situation and what they are going to achieve. From the three case studies, the goal for the strategy development is concerned about the product, business plan and collaboration plan as the outcomes. Therefore, the demonstration put more weight on the producing process which the output being termed as ‘product’ is the final goal. Here, the research chose Journey Mappings as the visual structure which include the production by externally showing the timeline and journey before, during and to the end of the product development. Hence, we replicate at least three journey mappings for each of the case studies so that each of the groups can have more divergence and options during the strategy development. Then, the researcher also provided a blank paper for freestyle sketching for details in discussion (if needed). The example of journey mappings that has been used as the lower level visual structure is shown in Figure 6.4 (a), then the journey mapping completion throughout the focus group observation is shown in Figure 6.4 (b). This one was taken as the sample from focus group 1.

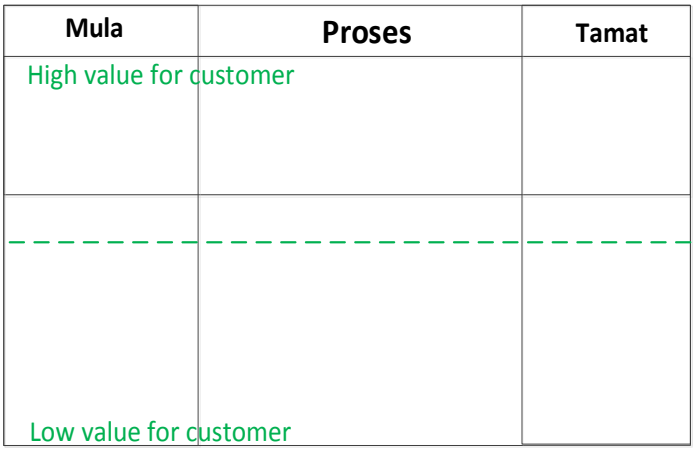


Figure 6.4 (a) The Journey Mappings as Lower Level Visual Structure (before the Focus Group Observation

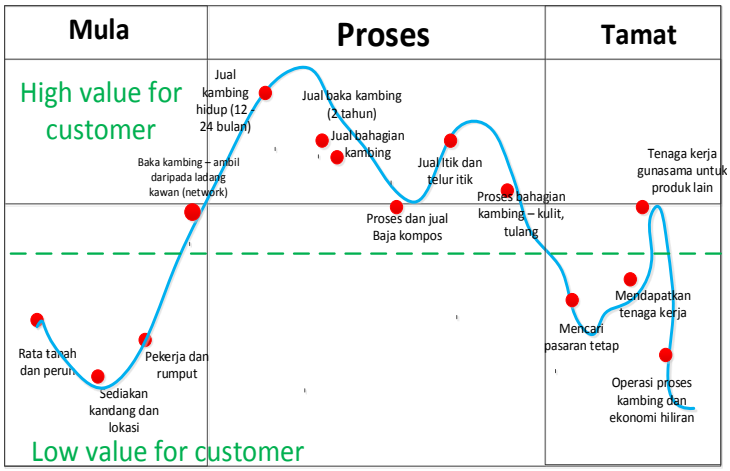


Figure 6.5 (a) The Journey Mappings as Lower Level Visual Structure (after the observation-example taken from Focus Group 1)

Furthermore, the strategy development also needed to consider four key components of strategy planning during the product development – financial, profit (people), production (operational) and R&D (learning and growth). Since the financial is compulsory among the other key component discusssion, then three lower level visual structures are needed to handle each of the key components of profit, production and R&D. The demonstration selected the List-Shortlist and SWOT Model (Strengths, Weaknesses, Opportunities and Threats) structure to facilitate the analysis of their internal and external situation, and can act as an ice-breaker to help the users from various fields to share their initial understanding of the situation so that they can move forward to the convergence phase gradually. As a lower level visual structure, it is able to support drilling into the lower level details. An example of the SWOT model is like Figure 6.6.

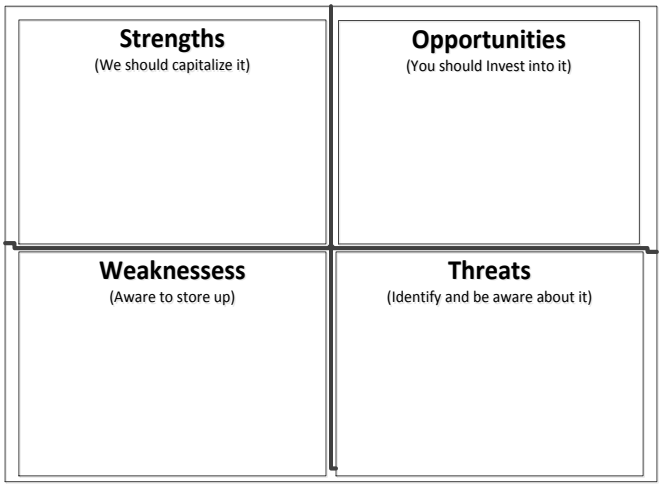


Figure 6.6 The Selection SWOT as Lower Level Structure for Key Strategy Components.

c Interconnection Between Higher and Lower Level Visual Structure

To handle the higher level thinking during the analytical and synthetical process, the demonstration must consider the organization and structure between higher levels of abstraction and lower level details of visual structure. Users develop abstractions of the higher levels by accessing and manipulating the lower level details. Therefore, the relationship between these lower and higher elements is important to facilitate the reasoning process. To support the process, we organize the visual structure according to the process of developing a business strategy. For example, a group of users needs to focus more on the product and operation development while needing to pay attention to the financial, sales and R&D elements.

We propose the organization of visual structure from an assumption of going from abstraction to details (please refer to Figure 6.7) – from the bottom to the top part or from right to left. The lower or right part is to encourage discussion of lower details. The mapping journey has been put at the lowest level of the visual structure and it is meant to help the understanding of the 'state of the art' of each of the elements, perspectives, or departments. At the middle level, the SWOT models or list-shortlist has been placed to guide the analysis process to encourage higher levels of abstraction. The visual mapping at the top part is meant to support the synthesis of the cognitive process so that convergence of ideas and ideas can take place over time. As a whole, the group is able to view the higher and lower level at the same time. They

can view, relate and refer to the details during the reasoning for a higher level abstraction. The visual structures have been organized according to the strategy phases and in doing so helps to structure and arranged their discussion in a more orderly manner.

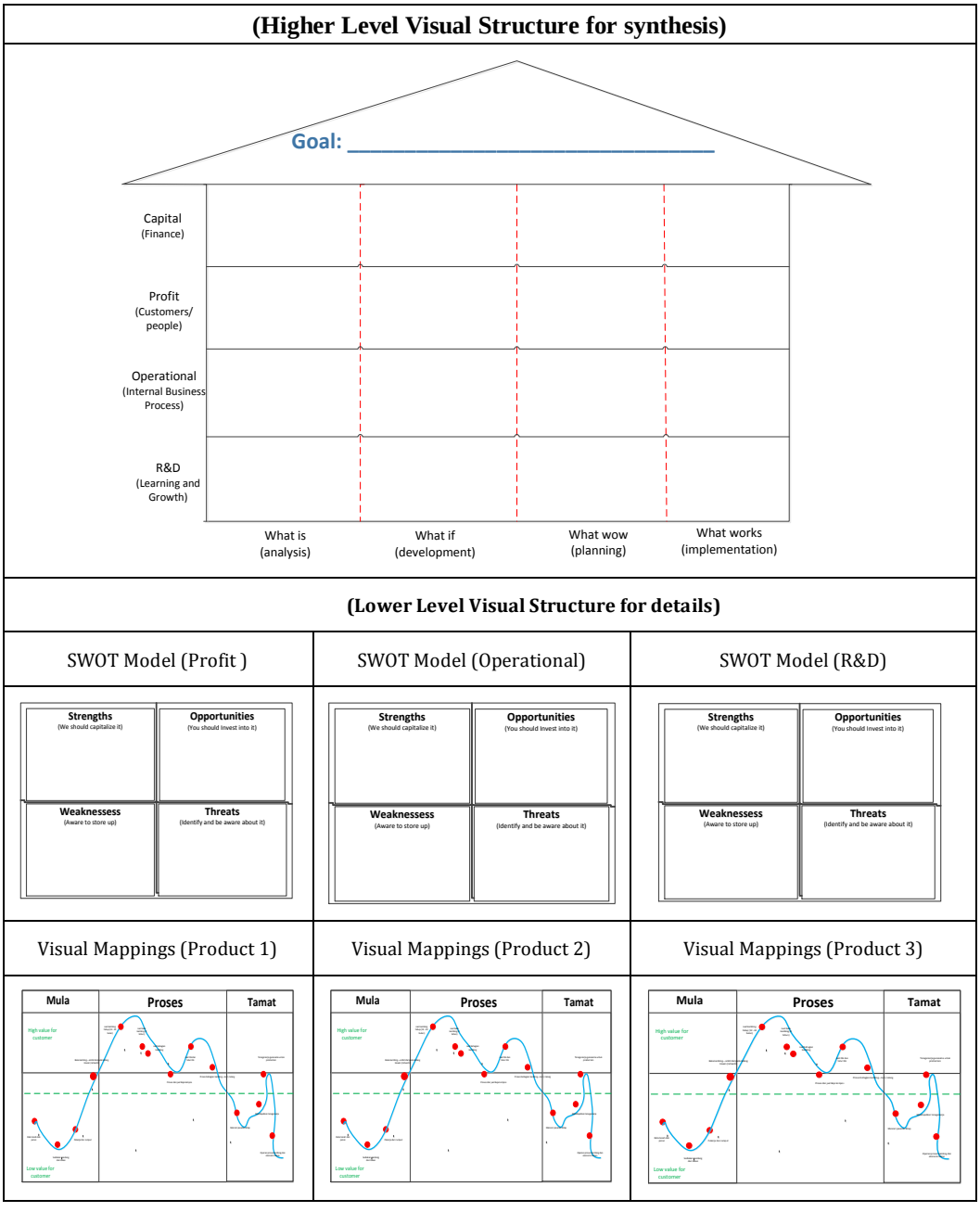


Figure 6.7 The Demonstration for Systemic View of Visual Structure Synthesizing

6.2.3 Demonstrate Open Ended Organizing and Structuring.

From the previous principle, the demonstration of Visual Structure Synthesizing should be capable to come out with the complete structure. In addition, the third visual design principle is meant to complement the structure from the perspectives of interactivity. By having the limitation for the prototyping based on a paper mockup, this method of prototyping enables the visual representation design to be a visual representation instrument that is workable to be tested during the focus group observation. Even though it is a simple and cost saving, yet practical to be used during the Collaborative-CCA process. Another benefit is the paper-based mockup supporting the visual structure interactivity as being open ended organizing and structuring and the prototyping is flexible and free-and-easy to use since the users can see, write, draw, delete and add information on the visual structure based on their needs during the evaluation. Moreover, the paper-based is less sophisticated than a software prototyping, and is more like an unfinished product that is capable of catering the needs of perceived finishednes and modifiability on the prototype, so that the users will feel more comfortable and motivated to ammend the visual structure. Lastly, the paper based-mockup allows the dynamic interactivity that is seldom and expensive to have due to current market technologies.

To remind the participants about an open-ended interactivity approach, before the experiment, the researcher will explain the importance of the group to use the visual representation instrument as a one point centre to guide the strategy development process, in which they can identify the elements provided as the key points to trigger on ideation or consideration. Moreover, they can write, draw, delete, relate and mark any information based on their needs during the collaborative-CCA process.

6.3 THE USEFULNESS OF VISUAL REPRESENTATION INSTRUMENTS TO SUPPORT COLLABORATIVE-CCA PROCESS.

After demonstrating the Converge-VRD into Visual Representation Instruments, this instrument will be used to facilitate the Collaborative-CCA process during the focus

group observation. The observation supports the research in terms of (i) demonstrating the usefulness of the instrument to facilitate the Collaborative-CCA process and (ii) evaluating the usefulness of the instrument in facilitating the Collaborative-CCA process. However, this section will concentrate and elaborate more on the demonstration of instrument usefulness and the next section will further present the evaluation results and findings. The demonstration will be justified through an observation that is recorded via audio, video and visual representation contents. Even though the description will generally describe the demonstration usefulness from all three case studies, the thesis will mainly use the picture and diagram from the case of group 3 (collaborative decision strategy for public sector professionalism) for the purpose of consistency.

6.3.1 The Usefulness to Facilitate the Strategy Development Process

The demonstration found the usefulness of visual representation instrument to facilitate the strategy development process during the focus group observation, in other words, it justified the usefulness of Converge-VRD to facilitate Collaborative-CCA process. From the Converge-VRD demonstration, the design will be executed into an applicable visual representation instrument. In this case, the paper-based prototyping has been used as the instrument's platform (please refer to Figure 6.8) during the focus group observation. Due to limitation on the CCA domain, the research had turned the Converge-VRD into an applicable instrument according to the domain of strategy planning and its context of use. Therefore, from the observation, the research can see the potential of this instrument to facilitate the users to develop the strategy planning.

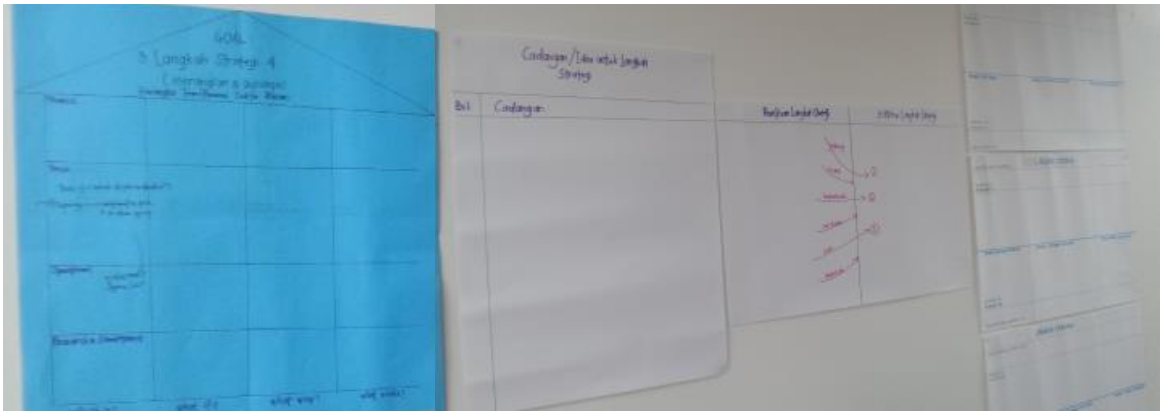


Figure 6.8 The Visual Representation Instruments on the paper-based prototyping (example from Focus Group 3)

The paper-based instruments will be put in front of the group to facilitate them during the experiment. The overview setting of the instrument during the experiment is shown in Figure 6.9. The users were reminded to use the instrument as the guidelines, reference and white-board base. Since the paper-based instrument is open ended, it is free and easy to use and, due to the unfinished look has encouraged the users to amend it.

Figure 6.9 The Overview of Paper-Based Instruments in the Collaborative-CCA Process (example from Focus Group 3)

The visual representation instrument is useful as a main reference during the discussion among the group members. The group used the instrument to guide them to handle each of the task in achieving the activities' goal. The elements provided in the higher level visual structure (the paper in blue color) serve as the points to guide the process and trigger an ideation in the lower level visual structure (List-shortlist,

journey mappings and free style sketching). They also can write, draw, delete, connect and mark any information in the lower level visual structure based on the need during the Collaborative-CCA process.

Hence, interactivity between all these information (content and context) are explicitly shown, pointed and remarked. These can influence the interactivity between the users and the instruments and the communication among themselves. One of the examples shown in Figure 6.10 is when one of the participant communicated among the group members to convince the abstraction of the think-tank group as the second strategy by using the details and elaboration from the lower level instrument (visual mappings). To convince this point of abstraction, the content inside the instrument will evolve when other group members give feedbacks during the communications. This process will iterate until the group is satistified to decide the think-tank group as one of the public service collaborative profesionalism strategies.

Figure 6.10 Clarify the Discussion Using the Instruments (example from Focus Group 3)

6.3.2 The Usefulness of Higher Level Visual Structure

From Converge-VRD demonstration, the applicable design for the higher level visual structure as shown in Figure 6.3 has been transformed into a paper-based platform and highlighted using a blue color background paper.

During the experiments, the research found 2 from 3 groups rarely put any content inside the higher level visual structure. Then after the experiments, the researcher had asked the group member about the function of the higher level visual structure (the diagram in the blue paper). The respondents from group 2 said that the higher level visual structure was useful because it eased their understanding about the process to be taken and the elements to consider during the experiment. Hence, they used it as the guidelines, while the content for details discussion about the understanding will be put in the lower level structure since it is a more proper place. The respondents from group 3 also agreed with the usefulness of the higher level visual structure as easy guidelines. Additionally, they mentioned the guidance on the basic elements let them have the similarity points of view to consider during the strategy pelan, especially for group 3 since each of the group members came from a different scheme of service in the public sector. They have different backgrounds, scope of works and interests that might lead them to have different points of consideration during the strategy development.

6.3.3 The Usefulness of Lower Level Visual Structure

There are three types of diagrams that have been used as lower level visual structures for the experiment: i) List-shortlist, ii) Journey Mappings and iii) Freestyle sketching. Each will be presented and explained in the next paragraph.

a List-Shortlist

The list-shortlist visual structure as shown in Figure 6.11 contributes as an intermediate between the higher and lower level visual structure. The list as shown in (a) plays a role to support the divergence phase in identifying the possible strategies. Then, from the lists, the group must converge to choose three best strategy plans using the shortlist visual structure as shown in (b). We can see that the users quite hesitated about the convergence process and took long time to come out with the three selections. For this reason, it is important to further clarify the convergence from the lists into the shortlist of 3 strategy plans. Through the visual mappings as the lower

level visual structure, each of the strategies will be elaborated and discussed as presented in the next paragraph.

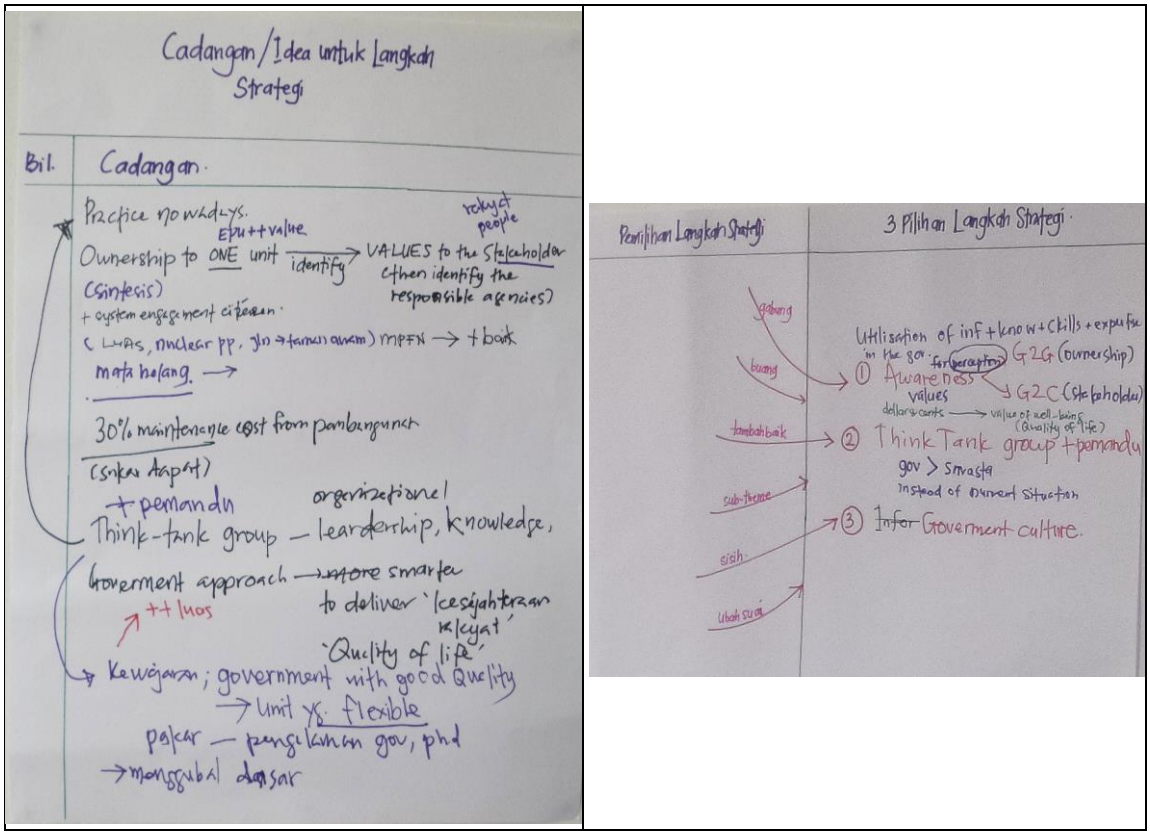


Figure 6.11 List-Shortlist Visual Structure (example from the Focus Group 3)
(a). List all the Possible Strategy Plans (b) Shortlist to Converge 3 Strategy Plans

b Journey Mappings

Since the goal highlighted 3 strategy plan to be develop, the group utilize all the provided visual mappings. Each of the visual mapping hold the details discussion for each of the strategy plan as shown in Figure 6.12. The experiments showed the usefulness of the lower level visual structure to hold the content of discussion. It is explicit about the points of discussion in which the users can see the evolvement of the constructive content throughout the discussion. From here, the users have the reference to refine, amend and rationalize the convergence for each of the strategies as an abstraction point.

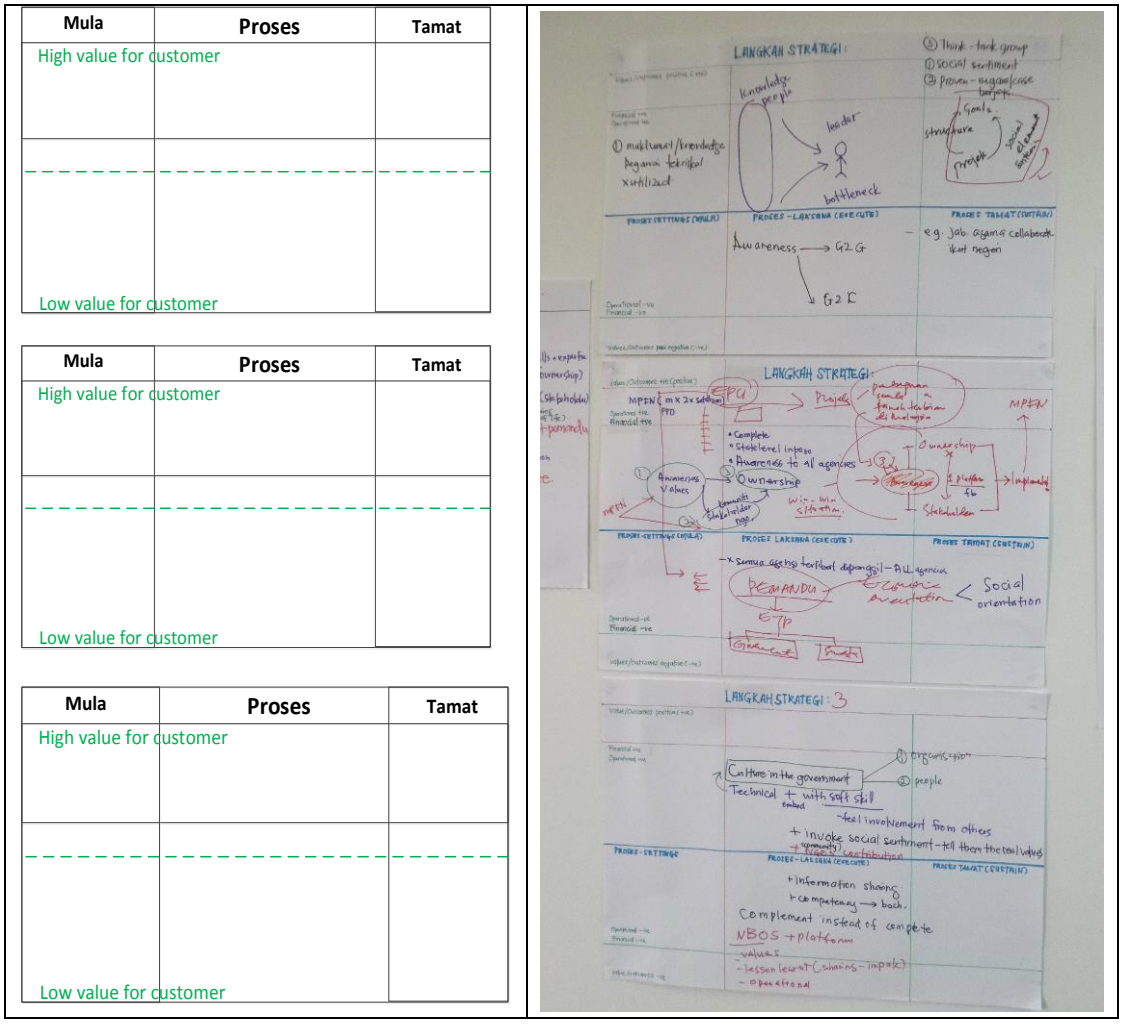


Figure 6.12 Journey Mapping for Detailings of 3 Shortlisted Strategy Plan
(example from Focus Group 3)
(a). Before (b). After

Additionally, we want to clarify the importance for the cycle of formation during the collaborative CCA process especially between the lower level visual structure (in this case is the visual mappings) and its intermediate-higher level visual structure (in this case is the lists-shortlist). As mentioned above (in paragraph i), the intermediate higher level structure used the list to diverge all the possibilities and then used the shortlist to converge into 3 strategy plans. For the lower level visual structure, each plan will be discussed and elaborated in details using visual mappings. The elaboration from the lower level visual structure was useful to rationalize the convergence for each of the strategy plans. The feedback looping process from lower level to the higher level and vice versa helped to refine, amend and rationalize the abstraction for each of the strategy plan. Furthermore, the highest level visual

structure (the Kaplan Model House on the blue paper) helped to elaborate and describe the lowest level of visual mappings in a more centered and relevant point of view, which indirectly helped to refine the abstraction to be more relevant. From here, the research found the convergence-divergence process from top-down or right-left (higher level to the lower level) help to identify the possible abstraction. Then the feedback loop from bottom-up or left-right (lower level to the higher level) helps to refine, rationalize and confirm the abstraction.

c Freestyle sketching (if needed)

During the demonstration, we also provided freestyle sketching (blank paper without any structure) because CCA is context dependent, thus any emergence condition can occur during the process. The free style sketching is useful to cater this need. As an example shown in Figure 6.13, group 3 needed an additional blank paper to explain the details about the value of the strategy to the stakeholders and *'pertindihan kuasa'* among the agencies for the third strategy plan – the central knowledge base. This sketch helped other users to understand the situation clearly.

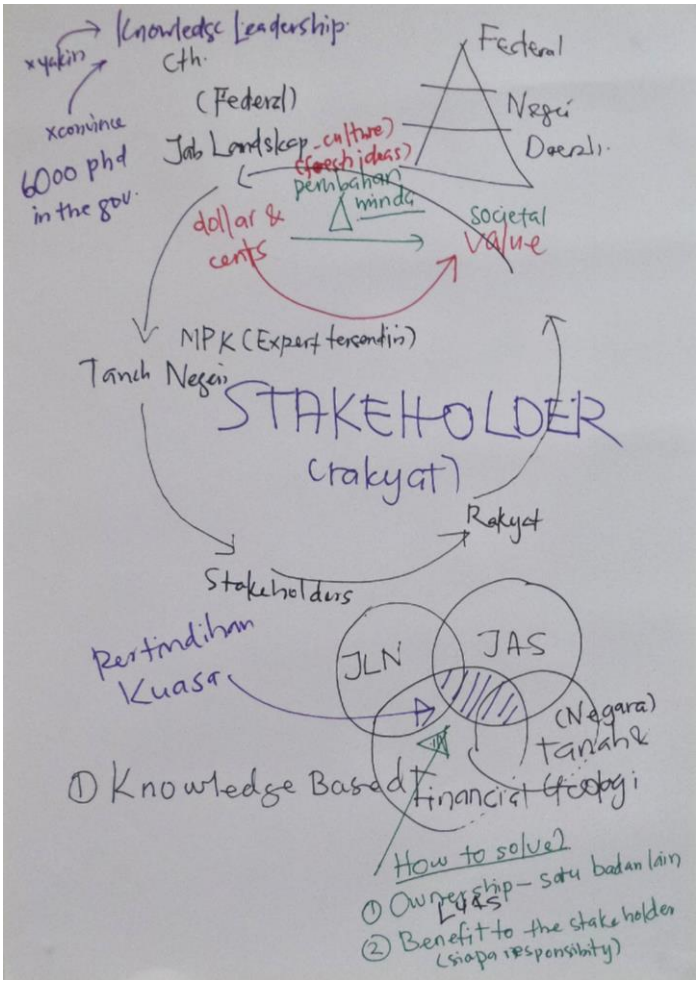


Figure 6.13. The Example of Free Style Sketching (example from the Focus Group 3)

6.3.4 The Usefulness of Open Ended Organizing and Structuring

The visual representation instrument is useful as contextual guidelines as shown in Figure 6.14 (a). The combination of multiple visual structures helped to coordinate, manage and organize the incoming of information content during the experiment. Through an open-ended and multiple feedback loops, users are free to amend and put new input in the instruments for every emerging information and idea, in addition to the instrument morphing itself to include new information. As a result, the users were able to construct and develop their knowledge according to the content construction in the instrument. At the end of the experiment, the visual structure has been filled in and utilized as shown in Figure 6.14 (b).

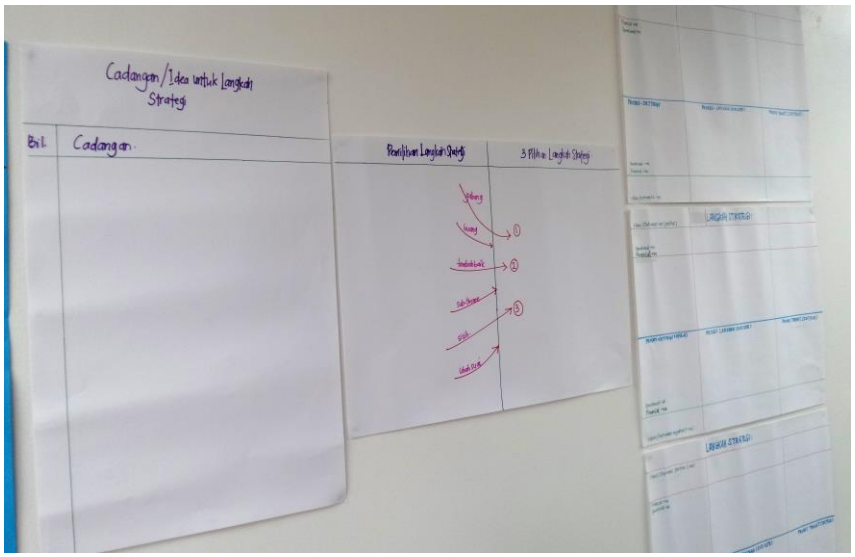


Figure 6.14 (a) Constructive Knowledge Throughout the Collaborative-CCA Process.(before the Collaborative-CCA Process)

Figure 6.15 (a) Constructive Knowledge Throughout the Collaborative-CCA Process.(after the Collaborative-CCA Process – example from Focus Group 3)

The visual structure arranged the information according to the tasks given, thus it helped to reduce the cognitive load by chunking the big amount of information into smaller portion and then structuring and organizing the information that helped to enhance the information processing. Further than that, an explicit visual structure was useful to hold the centralized memory during the collaborative-CCA process. The users have one point of reference centre to clarify and check the collective memories.

6.4 THE EVALUATION FINDINGS FROM FOCUS GROUP OBSERVATION.

During the demonstration of the instruments usefulness (section 6.3), the instruments were also being evaluated based on the three evaluation criteria as mentioned in section 3.8.3 (a). This section discusses the main findings in relation to the evaluation based on the observation for the interactivity process between the participants and visual representation instruments during the focus group observation. The results provide insights into the impact of the visual design principles that have been developed in Converge-VRD to facilitate the Collaborative-CCA process. Based on three evaluation criteria using theme and subtheme concept of DQA, the evaluation will access the capabilities of the Converge-VRD to: i) centralized and externalized the Collaborative-CCA guidelines, ii) facilitate the convergence process and iii) handle emergent pattern development. Each theme will be further elaborate in the next paragraph.

6.4.1 Theme 1- Capabilities to Centralize and Externalize the Collaborative-CCA Guidelines.

Table 6.4 summarizes the corresponding key ideas from evaluation that the Converge-VRD is able to (a) centralize the mental model and (b) bring clarities on the 'how' knowledge. These two subthemes justify the capabilities of Converge-VRD to centralize the Collaborative-CCA guidelines.

Table 6.4 Subthemes and corresponding key ideas to support the theme 1

Theme 1	Subtheme	Unit – Key ideas
Capabilities to centralize the Collaborative-CCA guidelines	(a) Centralized mental model	(i) Guidance for content construction (ii) Avoid blurriness (iii) Resolving task conflict
	(b) Clarities on how knowledge can be formed	(i) Guidance on what to do for each step of Collaborative process. (ii) Participants were confident during the process. (iii) The groups were able to execute and fulfil the job. (iv) Participants were satisfied after the process.

(a) Centralized mental model is our concern since CCA are performed in the collaborative settings and the design principles must be able to solve this collaborative challenge. Therefore differentiation and conflict during the Collaborative-CCA are the prime challenge that needs to be considered for this research. By having a visual structure that had been organized based on convergence and general system ideas, it gave the contextual guidelines while Collaborative-CCA would take place. Moreover, these guidelines were able to centralize the mental model between users and give clarity during the cognitive process.

From looking at the results, we found that discrepancy between the users had been the major challenge while they carried out CCA collaboratively. There was a difference in the participants' cognitive backgrounds because of their different mental models and perspectives. The MBTI results justified their differences. Therefore, by having a single visual structure to represent the discussion during the Collaborative-CCA, it gave centralized and contextual guidelines for constructive content during the conversations. The discussion content that had been picked, annotated and sketched in the visual representation structure was similar to the concept of thinking aloud. However, in a very visual way, the participants could explicitly see the gist of their arguments. This helped to break silo and leverage roles between the users. Additionally, since the participants only had one single point of references, the visual representation was able to reduce duplicating elements to be discussed over and over again. On the other hand, when the users were able to see the information discussed clearly, they felt in-control, had confidence, and were more open to discuss any issues.

Moreover, the contextual details of the visual structure helped to resolve further differences in what they saw the tasks at hand, so that the discussions were easier, more pragmatic, focused, and avoided time lost on clarification and eliminated disagreements. In focus group 1, sometimes the arguments turned tense when a participant demanded clarification on certain elements. In one case, a simple suggestion to see the representation from another participant led to clarifying a misunderstanding. The simple admission like *"Oooo… there"* while nodding his/her head seemed to help resolve the tension among the peers. Besides this, we could see that the participants were clearly exploring what they did not know, and it led to

knowledge creation as a group. Some of the issues that were raised were not easy to solve at some point due to the participants' lack of information because they were using the four elements mentioned in the structure of the Kaplan model (financial, people, operation and research development). When they realized that they cannot have further and solid information based on those four elements, then the chairperson or someone in the group suggested to stop and move to something else, and come back to this when more emergent information becomes available. As an example, for groups 1 and 2, they had certain issues that needed to have further investigation. G1P1 as the participant from Group 1 said *"We cannot prolong the chili since we don't know much about the fertigation process, how much money it will cost, how much profit we can get or whether it's easy or hard to maintain, so let's find out more and present it in the next meeting".* By realizing what they know or what they do not know, and admitting there would be new information coming, helped to avoid losing time for the group on discussing irrelevant issues.

During the Collaborative-CCA process, some disturbances occurred. Some participants started to chit-chat regarding the previous issue and something unrelated; someone's phone beeped; a few simply went out of the room for a short while. These somewhat disturbed their cognitive attention. However, by having the visual structure, we observed that the participants managed to get back into the current stage by referring to the current phase and what was annotated in the representation space. In addition, since the group annotated the gist of the conversations, the participants easily picked the missing content and got back to the track of the discussions. We attempted to support the theme of developing a centralized mental model. Table 6.5 summarizes the findings for the key ideas and sub-subthemes formation to help develop the centralized mental model subtheme and to support representing complexities.

Table 6.5 Key Ideas and Sub-Subthemes to Support Centralized Mental Model Subtheme

Subtheme	Sub-subthemes	Unit-Key ideas
(a). Centralized mental model	Guidance for Content construction	(i) Contextual of visual structure to guide content construction. (ii) Content sketching - Explicit thought – same like thinking aloud but using visual instead of voice.
	Avoid blurriness	(i) Reduce duplicating (ii) Highlighting explicit content (iii) Breaking silo (iv) Users feel in control and confident
	Resolving task conflict	(i) Capabilities to admit their own misinterpretation after clarities on the explicit content and context (visual representation) (ii) Participants know that they don't know (iii) Participants easily manage to get back into current stage during the performance of collaborative CCA – discuss which (after the participant was distracted and wanted to get back to the discussion

(b) Clarities on the 'how' knowledge formed during the discussion is important to let the users understand what to do during the exploration process. The participants was alert and able to manage the task in order to fulfil the main drivers and objectives of Collaborative-CCA.

The findings from the focus group observation show that the participants were clear about the important phases to develop in the strategy planning. The findings from the case studies have shown that the group were clear about the important phases to formulate the strategy planning. While referring to the compact, simplified and anchored Kaplan Model structure (acting as a higher level visual structure), the participants were able to understand the importance of the interconnections between the elements of the financial, customer, internal business process and learning and growth. For group 1, even in the early 03:28 minutes from the whole 124.07 minutes of discussions, the participant of G1P2 (the financial controller) and G1P1 (the land owner) were nodding their heads while the researcher explained the strategy elements, phases and the feedback loop between each of it. Even without detailed guidelines (e.g. list of tasks, documentation and details instruction), they were capable to act effectively in order to complete the objectives. We found that simplicity of the structure (e.g. division of the rows and column) and terms (e.g. financial to model, people to customers) helped the participants to easily absorb and grab the 'how'

knowledge on developing their business strategy planning. Even the simplification might have changed the true meanings of the real process but it seemed real and workable for their context. Meanwhile the other participants in the group were confident while conducting Collaborative-CCA. Even for the rest of the case, it could be clearly seen from their face reaction that they understood what they were going through. The face gestures indicated they have reached the 'a-ha' condition in understanding the business process as a whole. It showed that they just understood each of the steps needed to be taken during the Collaborative-CCA process.

Furthermore, the participants were satisfied after the performance because they were able to complete the tasks, understand clearly on what they were doing and clear on what to do after the discussions. These were mentioned in interviews with selected participants after the experiments. Among the answers from the participants were *"….Yes, I clearly see what the pelan is and then we know what to do next"* (Participant G2P3), "*We should have this thing (refer to the instrument) in our meetings and let the boss see what we see"* (Participant G3P4) and *"….all right, things for sure… we want to schedule monthly meeting and compare our project progress to this (referring to the summary of the business planning in the Kaplan Model House)"* (G1P2). Moreover, the confidence and satisfaction could be seen from the participants' face impressions, body gestures and enthusiasm. During the Collaborative-CCA performance, they volunteered to give suggestions and ideas. Since the case studies were taken from the real case, the participants were able to find ways and eager to execute their planning. Even after the session, the participants were still talking about their discussion findings with smiles, laughter and enthusiasm that indicated they were satisfied with the discussion and gained confidence to execute the plan.

6.4.2 Theme 2 - Capabilities to Facilitate the Convergence Process

By observing the interactive process between the participants and the instruments, we found that the participants managed to understand the main drivers and were able to see and draw the interconnection between various elements to construct the new

perspectives. The key ideas emerge from DQA to support users on convergence as shown in Table 6.6.

Table 6.6 Subthemes and corresponding key ideas to support the theme 2

Theme 2	**Subtheme**	**Unit – Key ideas**
Capabilities to bring an awareness about the convergence	(a) Clarity about the main drivers	(i) Knowing what to do in order to develop strategy planning (ii) Understanding the value of performing the discussion
	(b) Can observe and draw the interconnection between various elements	(i) Capacity to relate abstraction and details (ii) Capacity to construct new perspective

(a) Clarity about the main drivers are the most important elements in capabilities to converge during Collaborative-CCA. They represent the goals that need to be achieved. The research highlighted the importance of the visual design to guide and structure the cognitive process. The findings showed the participants had developed their understanding on what to do and achieved this in the early minutes of the discussion. With only a primary structure based on strategy elements and phases, participants were able to understand their importance. This indicates that the synthesis of the visual structure was capable of letting the participants see the entire structure and further understand the ultimate goal to be achieved during the CCA process.

The users were able to grasp the value of performing Collaborative-CCA as an important component to help them in the decision making process. From the findings, we could see the structure and organization based on the context usage that had aided them to understand the real value that they needed to achieve. For example, at the end of the discussions, the participant expressed the value of performing CCA and how the visualization helped. This occurred after all the activities were carried out (in the 124:03 minute of 127:33). From our conversation, he summarized the following sentence after having a deep look at the whole context (structure) of visual representation and content (text in each of the visual representation structure) that focused more on the analysis phase of the operational element, *"We are doing feasibility study right? Either it is worth it or not to develop the land... If from here we can see [pointing to the instruments], it is not worth it – better for us to eliminate the project..."* (G1P4). This seemed to show that he understood that the value of

performing the discussion was actually to study the feasibility for the agriculture development for the 18 acres of land, and that the synthesis structured visualization helped him to achieve this understanding.

(b) Ability to see and draw the interconnections between various perspectives is essential to generate new knowledge and ideas. We observed from the results that the capabilities of the participants to converge the information was related to the capacity of them to relate between the general structure (Kaplan model) and the details for any particular perspective. The participants were capable of forming the categories from the product list details in order to develop a bigger picture of the operational side from a more abstract level in the Kaplan house model. The relationship between the details and abstract structure has been visualized by categorizing similar elements into groups and using keywords to link between the more abstract information to their details. As an example from group 1, as shown in Table 6.7, the group had listed 7 potential products. When they wanted to put the content from the operational perspective in the Kaplan Model, they first grouped converge the products according to the categories of livestock, short term and long term. Since the explicit structure of details had listed out all the products, it eased the analysis phase to compare, identify similarities, relate and produce the group in more clarity. Then, for each category, they eliminated the products with the less forecasted profits and were difficult to manage.

Table 6.7 Process of Convergence (Example taken from Focus Group 1)

Products	**Category (new perspective)**	**Perspective**
Goat, Cow	Livestock	Operational Perspective
Tapioca, chilli and banana	Short term	
Jackfruit and Guava	Long term	

Table 6.7 shows that the process of abstraction from 7 different elements in the column ‘products’ produces 3 categories in order to form an abstract operational perspective. The abstraction process seemed to prove that the systemic view of the visual structure had been capable to guide the process of developing interconnections between different elements to produce new perspectives. By gaining these two elements from a systemic point of view, it afforded developing real understanding of the overall situations. On one hand, understanding the interconnections between the

various elements gives the users preparation to manage any emergence of information, ideas or tasks. Most importantly, they are able to find an adequate level of details and abstraction. The capacity to relate abstraction and details, in addition to seeing the interconnection from various elements, offers the basis to construct new perspectives and this is the beginning of producing innovations. On the other hand, a clear understanding of the main drivers let the users have a shared understanding of the goal of collaborative CCA. It gave a common awareness to each of them.

The research does understand that even the capability of visual design is capable to let the users understand about the main driver and be able to see and draw the interconnection between various elements but it doesn't guarantee that the Collaborative-CCA process is able to come out with the converge-integrative solution all the time. Hence, the awareness about the main driver and explicit interconnection might help and drive the users to perform one.

6.4.3 Theme 3- Capabilities to Handle Emergent Pattern Developement

The prime challenge in analysing a complex scenario is that we cannot determine *a priori* of some issues and patterns, as these are often unpredictable, emergent and unique to the situation. It requires new solution, ideas, innovation, and evaluation to bring benefit to the end. Thus, users need to handle emergent issues with an open-ended, dynamic and flexible mindset. Basically we were able to identify similar key ideas to perform two subthemes to support theme 3. Table 6.8 summarizes the ideas extracted from the complementary triangulation and the subtheme formation during the analysis.

Table 6.8 Subthemes and Corresponding Key Ideas to Support the Theme 3

Themes	**Subthemes**	**Unit – Key ideas**
Handling emergence pattern	(a) Contextual guideline for knowledge construction.	(i) One point of collaborative reference. (ii) Guidelines for inductive process. (iii) Verification of individual with collective emergent information.
	(b) Extend mental model for constructive content	(i) Extend mental model during knowledge assimilation. (ii) Holding collective memories of discussion. (iii) Act as the check points. (iv) Points for more elaboration.

(a) The visual structure acted as contextual guidelines for knowledge construction. As discussed previously, the benefit of visual structure is to help form a centralized mental model between the users. Also, it provides cognitive guidance during the knowledge construction. In order to construct new knowledge, especially in decision making processes, one requires an ability to deal with incomplete information and be able to connect variables that may change over time. Then the process of constructing and assimilating new knowledge from various elements happens '*in their own head*'. It is difficult to know what happens in people's heads. We observed that sometimes the participants were taking notes on the important issues personally and in silo, separate from the group. However, because of having the visual structure as one point of reference, it gave the contextual guidance throughout the process of cognitive induction, and slowly participants were seen less in-silo type of note taking. We noticed that over time all the groups were having similar patterns of behaviour and annotated personal content inside the same visual structure, and this is especially the case during the induction knowledge process. The content was mostly from the important information items, gist and ideas or outcomes of their discussions. Even though the visual structure was not automated for all the decisions, it facilitated the participants in the assimilation, integration, and deducting what they had in their own head with what was visually shown in front of them. It helped each of the participants to compare, analyse and clarify their own judgement with the collective point of view. Indirectly, the visual structure was supporting the group to come out with a more realistic decision which was verified by other people in the group.

(2) The instrument also helps to hold the collective memories for discussion later. From the emergence perspective, one thing could be clearly observed, and that was that the contents of the discussion were not static, as they evolved throughout the entire session of discussion and new information would arise constructively and dynamically. Over time, the collective information became bigger and was overloading for one single participant to hold every single point and issue at hand. In an ordinary discussion, meeting or group work, certain people were jotting and sketching down the points throughout the process to lessen their cognitive load. From the three groups of case studies, we found many quotations referring to the instruments to hold the collective memories such as *"this one", "there", "ooo...that"*, and *"similar to this point right?"* while pointing to some content of the visualization using their body gestures, face impressions or eye contact. From this observation, we found the explicitness of representing the collective content through visual structure helped to extend the mental model during the knowledge assimilation. The users could rely on the content structure instead of remembering all the incoming information in their heads. Thus, they could manage their own cognitive load while assimilating new knowledge.

The instruments also acted as the checkpoints during the divergencee-convergence process. It helped the group to recall the previous salient points or highlighting new point of views. Some related comments *include "what else do we need?", "this done, done and done"* while ticking on the points in the list and *"do you see that we don't have any points about the integration of the knowledge sources?"* while referring to the instruments and yet provoking the others to check jointly on the content. Moreover, the content in the visual structure played the role as the focal point for more elaboration. A comment from a person in Group 3 (G3P5) said *"We already have that* (referring to the point of mediator body). *Why don't we just improve what we have?"* From this observation, we found the instrument helped to eliminate redundancies and added value to the current content.

6.5 DISCUSSION

The findings reported here were not homogeneous across all 3 groups. We have reported the general sense of the findings through DQA and found how it supported the themes that had been assigned according to the unit of data analysis. As the result, we have found that the core observation is that the VRD is capable of facilitating complexities of collaboration while people performed CCA. The evidence from the focus group observation show the key ideas in supporting the subthemes to clarify the 'how' knowledge construction and to act as a platform to develop a centralized mental model among the users. Three sub-subthemes have emerged to support the development of the centralized mental model among the users. We emphasized the significance of visual structure to centralize the mental model formation among the users by: (i) giving guidance during the knowledge construction through the use of elements in the visualization; (ii) avoiding blurriness and silo interaction; and (iii) resolving task conflicts for a better performance in the collaborative settings.

We can likely see that the users were being aware of the convergence while handling the information complexities. Even though the research was yet disable to justify the capabilities to facilitate the convergence (synthesis process), the systemic view of visual structure synthesizing was able to provide an understanding of the main drivers and capabilities of observing and drawing the interconnection between elements during the data analysis. These can spark an awareness that leads to the convergence process. Finally, the VRD also shows the positive findings in handling emergent patterns, a process in which the visual structure was able to act as the contextual guiding platform for knowledge construction and to extend the users' mental model. We summarize the findings as in the Table 6.9.

Table 6.9 The Summary of Evaluation Findings

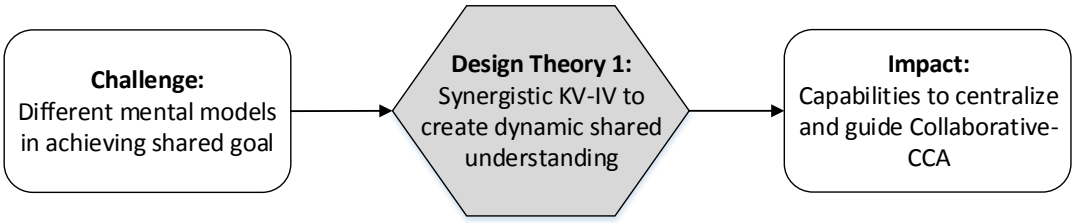
Main Findings	Elements	Descriptions from Focus Group Observation
1. Capabilities to centralized and externalized the Collaborative-CCA guidelines	(a) Centralized mental model	(i) Guidance for content construction (ii) Avoid blurriness (iii) Resolving task conflict
	(b) Clarities on how knowledge can be formed	(i) Guidance on what to do for each step of Collaborative-CCA process (ii) Participants were confident during the process (iii) The groups were able to execute and fulfil the job (iv) Participants were satisfied after the process
2. Capabilities to suppord Convergence ⇩ Capabilities to bring an awareness about the convergence	(a) Clarity about the main drivers	(i) Knowing what to do in order to develop strategy planning (ii) Understanding the value of performing the discussion
	(b) Can observe and draw the interconnection between various elements	(i) Capacity to relate abstraction and details (ii) Capacity to construct new perspective
3. Capabilities to handle emergent patterns	(a) Contextual guideline for knowledge construction.	(i) One point of collaborative reference (ii) Guidelines for inductive process (iii) Verification of individual with collective emergent information.
	(b) Extend mental model for constructive content	(i) Extent mental model during knowledge assimilation (ii) Holding collective memories of discussion (iii) Act as the check points (iv) Point for more elaboration

These evaluation findings will further clarify the relevancy of Converge-VRD in handling Collaborative-CCA challenges through the relevance cycle. The relevance cycle is the process to check the relevancy of the Converge-VRD as the solution by evaluating the effectivenes in handling the identified challenges in the Collaborative-CCA process. According to Hevner (2007), the relevance cycle is essentially pragmatic in DSRM to emphasize relevancy and make a clear contribution into the application environment as described during section 3.3. In this research, the Collaborative-CCA Process for the management team in the organization is the application environment. It consists of people, organizational systems and technical systems that interact to work toward a goal. By following a good DSRM that often begins with identifying and representing opportunities and problems in an actual

application environment, this research has successfully identified and represented a set of Collaborative-CCA challenges (Design Artifact for RO1) as an output from chapter 4. These outputs rationalize the development of Converge-VRD as the solution (Design Artifact for RO2). Finally, the Converge-VRD as the prime artifact from this research must be returned into the Collaborative-CCA environment for the evaluation (the evaluation output as summarized in Table 6.9). Based on the process and elements involved in the relevance cycle that have been described in section 3.4, the research will further explain the effectiveness for each of the challenges-solution-evaluation as the relevance cycle.

6.5.1 Relevance Cycle of Creating Dynamic Shared Understanding

Relevance Cycle 1 will explain about the relevancy of Synergistic KV-IV to create a dynamic shared understanding to handle the challenge of different mental models in achieving a shared goal. From the evaluation, the research found the capabilities of the principle for design theory 1 to centralize and guide the Collaborative-CCA process as illustrated in Figure 6.16.



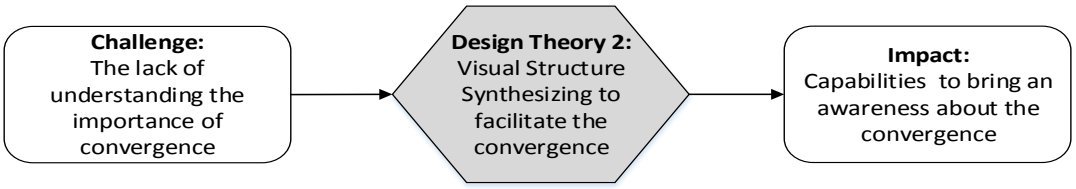
Challenges (rationales for design theory)	Impact during evaluation (effectiveness)
(a). Different roles of the users • Guidance is depending on the roles of the chairperson and secretariat. • The valuable and quality outcomes are depending on the roles, knowledge and skills of the users • The significance of secretariat roles in the multi level collaborative CCA • The differences between experts and decision makers point of view (b). Different level of knowledge • Know the content and context • Collaborator who don't know (c).Different skill of communication, type of learning and background	(a) Centralized mental model • Guidance for content construction • Avoid blurriness • Resolving task conflict (b). Clarities - how knowledge can be formed • Guidance on what to do for each step of Collaborative-CCA process • Participants were confidence during the process and the groups were able to execute and fulfil the job • Participants were satisfied after the process

Figure 6.16 Relevance Cycle of Creating Dynamic Shared Understanding

From the challenge, the research found the elements of (a), (b), (c) and (d) cause the different mental model in achieving the shared goal. Thus, from the evaluation, by approving the capabilities of the visual representation instrument to centralize a mental model, the research found the effectiveness of Converge-VRD Principle 1 to facilitate different mental model among the users in achieving the shared goal of CCA. Further than that, the challenge found (b) the different levels of knowledge lead to identifying the knowledgeable and less knowledgeable users within the group. Certain users were unsure of the process and elements to develop a strategy. The guidelines through the visual structure are able to guide the 'how' knowledge. Thus, Converge-VRD Principle 1 is also effective in informing the less knowledgeable and being a reminder to the knowledgeable about the 'how' knowledge for the strategy development process.

6.5.2 Relevance Cycle of Visual Structure Synthesizing.

Relevance Cycle 2 will explain about the relevancy of Visual Structure Synthesizing to facilitate the lack of understanding of the importance of convergence. Even though the evaluation cannot guarantee the execution of the convergence process, design theory 2 is able to bring awareness about the convergence during the Collaborative CCA process as illustrated in Figure 6.17.



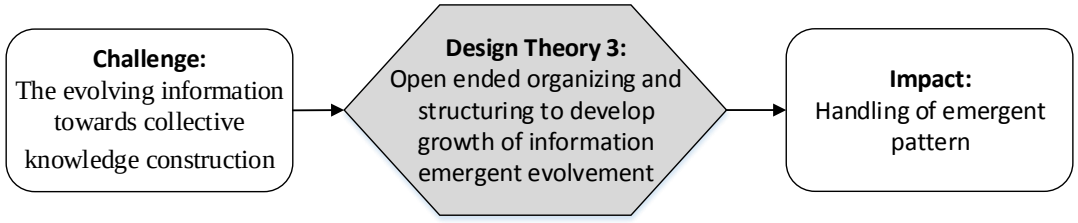
Challenges (rationales for design theory)	Impact during evaluation (effectiveness)
(a)The difficulties to clarify the main driver • The main driver is instructive (too tight) or abstractive (too loose). • Difficulties to appreciate the value of main drivers and sustain the main driver direction (b) Lacking for Interconnection • Separative job oriented thinking and the users are in the determination approach • No guidelines during higher level thinking and mental overload	(a) Clarity about the main drivers • Knowing what to do in order to develop strategy planning • Understanding the value of performing the discussion (b) Can observe and draw the interconnection between various elements • Capacity to relate abstraction and details • Capacity to construct new perspective

Figure 6.17 Relevance Cycle of Visual Structure Synthesizing

The evaluation shows the capability of visual structure synthesizing to let the users know what to do and understand the value of what they are doing in the collaborative CCA process. By understanding the value and vision will lead the CCA process into the right direction. Even though the evaluation cannot guarantee an integrative solution, providing an overview in a structured manner will help the users to observe and draw the interconnection between various elements. The combination of these two elements will effectively bring awareness that leads to the convergence phase during the Collaborative-CCA process.

6.5.3 Relevance Cycle of Open Ended Organizing and Structuring

Relevance Cycle 3 will explain about the relevancy of open-ended organizing and structuring to the develop growth of information emergent evolvement. From the evaluation, the research found the capabilities of design theory 3 to handle the emergent pattern during the Collaborative CCA process as illustrated in Figure 6.18.



Challenges (rationales for design theory)	Impact during evaluation (effectiveness)
(a)The evolvement from input and (b) output of the cognitive process • Hold a massive amount of evolving information • Evolving information without groundings. • Abstraction	(a) Contextual guideline for knowledge construction. • One point of collaborative reference • Guidelines for inductive process • Verification of individual with collective emergent information. (b) Extend mental model for constructive content. • Extent mental model during knowledge assimilation • Holding collective memories of discussion • Act as the check points • Point for more elaboration

Figure 6.18 Relevance Cycle of Open Ended Organizing and Structuring

From the challenge, the research found the elements of (a) and (b) cause the evolving information towards collective knowledge construction. Thus, from the evaluation, by approving the capabilities of an open ended organising and structuring, the research found an effectiveness of Converge-VRD Principle 3 to handle this challenge. Converge-VRD has provide the contextual guidelines to coordinate and organise the information content throughout the Collaborative-CCA process. The contextual guidelines are effective to ground the massive and evolving information by chunking, structuring and organizing the information content, which helped to manage the participants' cognitive load and information processing to construct and develop new knowledge. Furthermore, explicit information content and context in the visual representation space act as collective and centralized memories during the Collaborative-CCA process. It helped to extend the participants' mental model during knowledge assimilation, act as the checkpoints and cue for more elaboration during the abstraction.

6.6 CONCLUSION

The evaluation has approved that Converge-VRD is effective in facilitating the Collaborative-CCA process. In terms of the 'how'knowledge, we would like to highlight the rigor process in evaluating the Converge-VRD from the knowledge base (as shown in Figure 6.1). Based on DSRM, two important phases during the evaluation are the demonstration and the evaluation. The demonstration is essential to turn the Converge-VRD into a visual representation instrument and then demonstrate the instrument's usefulness in the real environment. To turn the Converge-VRD into visual representation instrument, step 1 applied the Converge VRD design principles by limiting the CCA on strategy planning and applied MBTI and the periodic table of visualization methods. We take into consideration that these limitations are examples and only meant for this particular study. The visualization communities are open to demonstrate the Converge-VRD according to their perspectives and preference. In step 2, by deploying on a paper-based prototype, the instrument's usefulness has been demonstrated via the focus group observation.

During the instrument's demonstration, the evaluation further accessed the effectiveness based on the identified criteria, evaluation guidelines and DQA. Via the relevance cycle, the effectiveness for each of the visual design principles has been accessed by comparing the impact from the evaluation results in handling the Collaborative-CCA challenges (identified from chapter 4).

Finally, there were two important outcomes during the evaluation. The first one is the evaluation results that directly contribute to justifying the effectiveness of the Converge-VRD in handling the Collaborative-CCA challenges. The second one is the evaluation guidelines that contribute to the evaluation process especially for the visualization communities. This will be further discussed in chapter 7. In terms of evaluation result as an outcome, this research showed the potential of Converge-VRD to handle CCA especially in the collaborative settings. Looking from the lenses of collaborative visualizations, we have found that the challenges arise to represent the complexities of CCA and the design must be fit with the context of group use. In collaboration settings, the visual representation design is not only supposed to handle the technical elements of information coding and cognitive elements of human perception, but must also consider the interactivity aspects of human- visual representation.

The core findings from the evaluation justify the benefits of Converge-VRD to represent complexities of collaboration in CCA. Visual design principle 1 shows the significance to help develop a centralized mental model and to bring clarities during the performance of Collaborative-CCA. Our design theory approach to synergize KV and IV principles has provided some foundations to inform the design of Collaborative CCA-friendly visualizations. It has the potential to bring an understanding of the knowledge context as used in KV to complement the formation of visual representation structures in IV. Moreover, visual design principle 2 by relying on general systems thinking, shed more light on the convergent aspects of the visual structure and organization. The visual structure synthesizing has been able to provide a more systemic view of the interconnections between various elements, hence supporting the users better in gaining awareness of the convergence. Finally, visual design principle 3, by mainly being based on second order cybernetics theory is

able to frame the idea of open ended visual representations, and provides dynamisms and flexibility to knowledge construction and extension for collective mental model development among users. It is also interesting to find that the overall findings lead to the potential of the visual structure as the foundation to spark the innovative thinking during the cognitive process (the innovation will be further discussed in section 7.4).

Via the evaluation chapter, we demonstrated how to ‘connect pieces’ between interdisciplinary fields in solving the Collaborative-CCA for the organization. The integrative approach is able to bring values from the academic field to benefit the practice in the organizations. By demonstrating the use of the VRD in the real settings of organizations, Collaborative-CCA can be viewed more practically when Collaborative-CCA occur. The value of visual design should be more concerned with the benefits to the teams which are definitely context dependent and deal with emergent information dependent issues. Even though, the visual structure is simple and far more basic than other proposed visual technologies, we found the strength of the visual structure with the proper usage is able to facilitate the Collaborative-CCA with more practical and meaningful uses.

CHAPTER VII

RESEARCH CONTRIBUTIONS AND FUTURE UNDERTAKINGS

7.1 INTRODUCTION

This chapter discusses the research contributions as the outcomes, meaning and implications of the research by revisiting the justification, research questions, methodology and key findings of this thesis. Furthermore, this chapter also discusses the limitations and future research directions to the visualization fields and its users, particularly for the one involved in Collaborative-CCA phenomenon. As the last chapter, generally this chapter as the conclusion to the thesis. From methodological perspectives, the design artifacts (DA) is the output from the DSRM. In a larger extent, DA is an attempt to bring an effective solution for the environment domain. In this case, DA is the visualization solution for the Collaborative-CCA phenomenon. Based on human-activity centric visualization, the solving methods are being more pragmatic by considering more on the problem as the root cause of the complexities phenomenon. Thus, by answering why the human needs to deal with information complexities, then able to answer how is the most effective visualization is as the way to facilitate it.

The exploration from chapter 4, 5 and 6 have brought us three DA as outcomes from the research: (i). DA1 – a set of construct challenges for Collaborative-CCA, (ii) DA2 – Converge-VRD as the visual design solution and (iii) DA3 – effectiveness evaluation for Converge-VRD. Hence, what do these DA mean? How can they contribute to the visualization as a body of knowledge and bring benefit to the users? To answer the question, chapter VII will further describe how the outcomes from the research will be meaningful and contributes to the visualization field especially on the

Collaborative-CCA context of use. Due to the DSRM perspective, the research need to further communicate the contributions by presenting, discussing and reviewing the outcomes to the relevant audience.

7.2 RESEARCH CONTRIBUTIONS

There are basically TWO (2) research contributions from this research: (i) Visual representation design to facilitate the Collaborative-CCA and (ii) An understanding of process design to guide the specific use visualization. To enhance the credibility of the contributions, the research design process further review the contributions with the experts in the field as presented in the design process in Figure 7.1. By reflecting the problem statement and findings from chapter 2, the research communicate the research outcomes to its relevant audience - an experts in the DSRM and visualization field. Then the further discussion within this chapter is the outcomes after the communication with the experts in the fields.

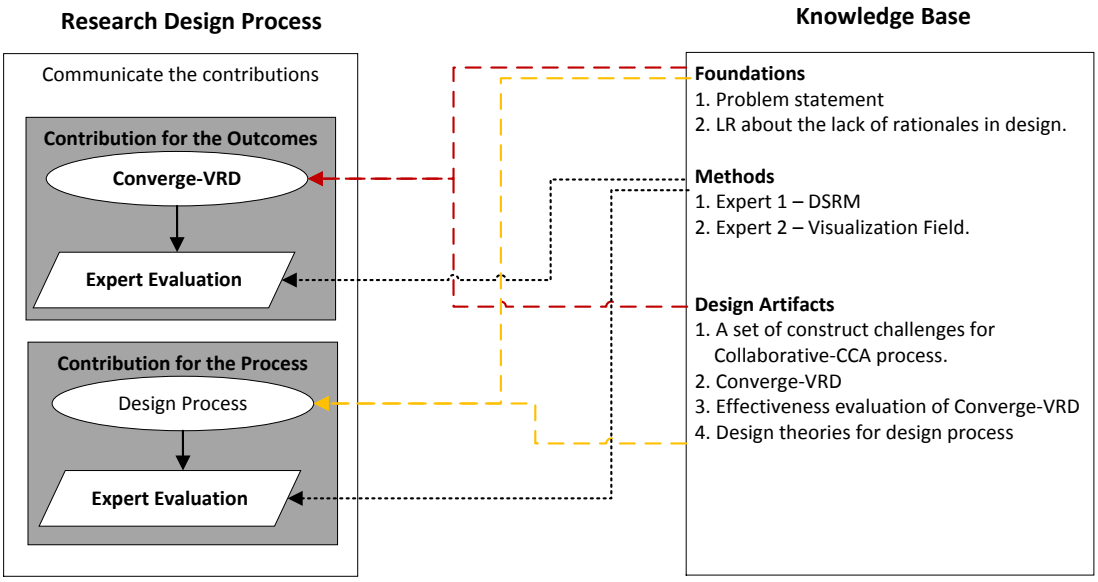


Figure 7.1 The Research Design Process to Communicate the Research Contributions.

As presented in chapter 4, 5 and 6, the research aimed to achieve an effective visual representation design to facilitate Collaborative-CCA process through the credible research design process as shown in Figure 7.2. Through the relevancy cycle, the evaluation results from RO3 has justified the effectivenes of RO2 to handle RO1,

which will be further explained in the Contribution 1. Then through the rigor cycle, the research design process demonstrates the applicable visualization design process for specific use that will be further explained in the Contribution 2. Thus, two essential contributions that give meanings to the visualization fields and its users will be further discussed within this section:

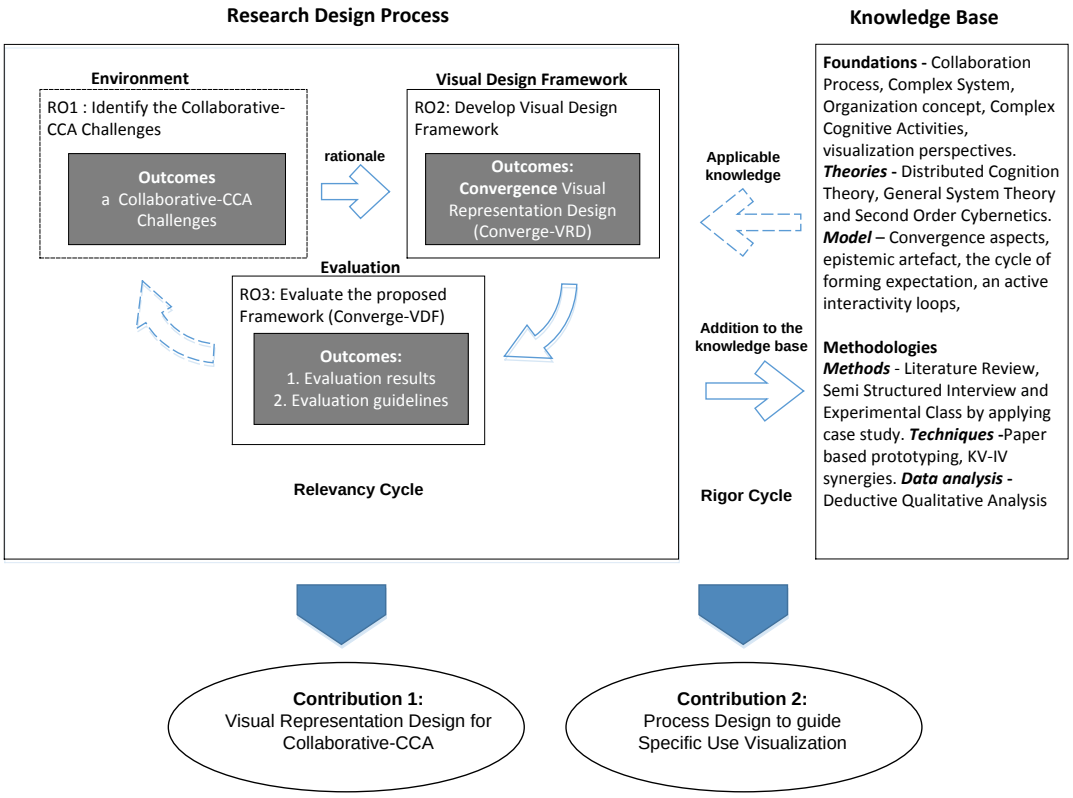


Figure 7.2 The Research Contributions

7.2.1 Contribution 1 – Converge-VRD to Facilitate Collaborative-CCA

Cognitive is the central of attention in the visualization fields. Manipulation in visualization is basically aimed to support, facilitate, reduce and enhance the human cognitive. These DAs have shed some light and create awareness in the visualization community about the cornerstone of design due to the specific context of use, especially in handling the Collaborative-CCA phenomenon as illustrated in Figure 7.3. From this research, we understand that manipulating the visualization in Collaborative-CCA is not only meant to reduce the cognitive load and amplify the memory storing and encoding. More than that, the visualization must be able to play a

role in facilitating and guiding the complexities of cognitive process and social consideration in terms of collaborative settings while performing the CCA. |

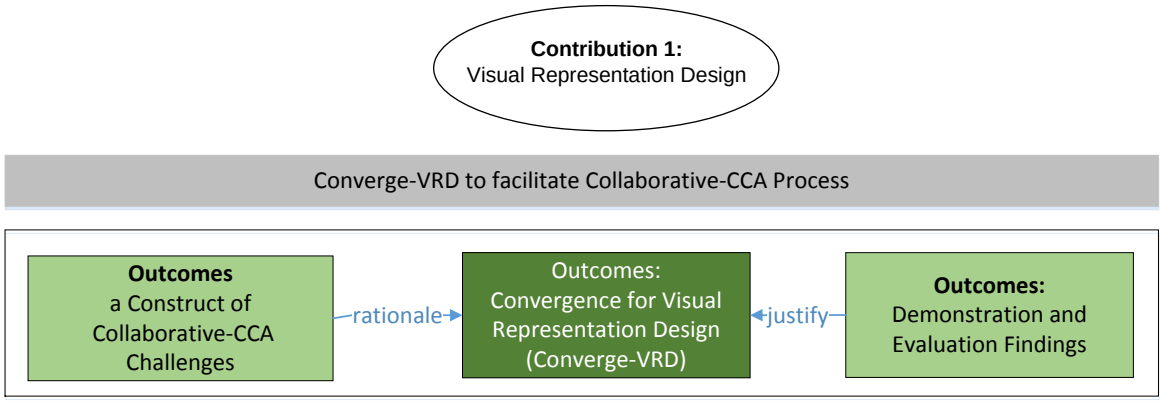


Figure 7.3 The summary of design artifacts in designing effective Collaborative-CCA visualization

From the figure above, the research highlights that the prime artifact is DA2 – Converge-VRD. However, DA1 is important to support and rationalize the development of DA2 and DA3 is crucial to justify the effectiveness of DA2 in handling DA1. Therefore, the paragraph below will further elaborate each of the DAs in contributing to Collaborative-CCA as specific context of use visualization. In spite of bluntly using and taking all the DA, this research encourages the visualization community to understand and grab the relevency of the DAs' usefulness. Due to the creativity, theorizing and practicality of visualization and design fields, this research also welcomes an enrichment for the identified DAs. The visualization community might have other perspectives for the set of challenges, a different way of design solution or evaluation enhancement due to facilitate Collaborative-CCA. Thus, the visualization community might consider to use or enhance these three DAs in a sequencing set or manipulate them separately.

a Design Artifact 1 (DA1) – A set of Challenges for the Collaborative-CCA Process

The research found DA1 is useful to provide rationales in developing design theory in RO2. DA1 offers an understanding about the challenges in the Collaborative-CCA phenomenon and answers why the users need to deal with the information complexities. Furthermore, its cornerstone the perspectives of handling the information complexities in the case of specific use visualization by providing the reasoning from its context. Instead of resolving the massive, messy, multisources and real time of the information complexities from the perspective of computerization and database, the solution concentrates on handling the information complexities by bringing more value and usefulness for its context of use. We believe it can spark a new point of view, creation and extension of visualization for the context of collaborative-CCA facilitation.

In its larger extent, DA1 contribute to the reasoning in providing the facilitation for information complexities. It provides some cues for Sitohang (2013) ponders on the value of successful of big data to handle the increasing volume, variety and velocity of information complexities. DA1 as a set of Collaborative-CCA challenges creates an awareness about the needs of the phenomenon to be supported and extends the value of visualization while facilitating information complexities. From here, the research found the needs of the facilitation from analysing cognitive process to the synthesizing cognitive process, in which is the extention from the lower level of events, actions or tasks to the higher level of CCA. Thus, the visualization needs to improve the value of visualization by expanding the facilitation to the higher level of cognitive process and activities. From here, the research found that the facilitation for information complexities is heading to the right direction, especially on the analytical cognitive parts for analysing complicated and massive of information complexities. However, the dissatisfaction from business perspectives occur because business people are expecting more than analytical facilitation. If we are looking from Sedig's CCA division, we can understand that the computer supported visualization facilitation (e.g current BI dashboard, big data, KM tools) is supporting the analytical on certain tasks, actions or events. However, the business people are expecting more than that. They need the facilitation to help them on the higher level from the

analytical, in which are the phases of synthesizing and creating new knowledge during the CCA process.

Further than that, the research used the term ‘challenge’ instead of problem. By using the word challenge, the research wanted to emphasis the positive mode and intention to handle, cater, facilitate and coordinate the challenges instead of reducing, solving or eliminating the problem. In line with Liang et al (2010), we understand that the use of visualization in the complex cognitive matters is not meant to eliminate or reduce the cognitive load but coordinating and managing the problem is our priorities. Even though the main intention of the challenge is to rationalize and support Converge-VRD, hence the challenge itselft is useful as an expansion in the visualization-complex cognitive research, thus we hope the term ‘challenge’ will motivate other researchers to further investigate and expand the study of visualization in the complex cognitive condition.

b Design Artifact 2 (DA2) – The Converge-VRD.

The Convergence Visual Design (Converge-VRD) is the design artifact outcome from RO2. Generally, the methodology in identifying DA2 has been described in section 3.7 and the development of it has been discussed in Chapter 5. Converge-VRD is a solution for the Collaborative-CCA phenomenon. The research highlighted three visual design principles in order to overcome the Collaborative-CCA challenges. From here, we can say that Converge-VRD is an expansion and enhancement of various kernel theories for the conditions of Collaborative-CCA domain. Therefore, instead of applying and using these reliable theories, this research also improved these theories to be useful in a wider application domain. Therefore, for the specific use of Collaborative-CCA point of view, the visualization community is encouraged to develope the visualization tools and application based on the three visual design principles that have been proposed as Converge-VRD as summarize:

Converge-VRD Design Theory

A foundation to support interactivity between representation space and mental space during Collaborative-CCA Process.

Converge-VRD Principle 1: KV-IV synergy to create dynamic shared understanding.

a. The extension of KVF as the Guidelines to capture the context of use for Collaborative-CCA Process.

b. Rationales for contextual design of visual structure

Converge-VRD Principle 2: Systemic View of Visual Structure Synthesizing.

a. Lower level visual structure

b. Higher level visual structure

c. Interconnection between higher and lower level visual structure.

Converge-VRD Principle 3: Open ended interactivity approach for visual structure synthesizing.

a. The contextual visual design to support evolving content of information growth.

b. The contextual visual design to support elements of modifiability and perceived finishedness.

We claim that the proposed Converge-VRD is novelty based on rigour cycle that ground the research from knowledge base and then add back the knowledge into the knowledge base. Eventhough the convergence foundation was based from a long duration of collaborative research by Kalfschoten and the group (2000 – 2012). Notwithstanding, each of the convergence aspects has been developed as the visual design principles based on the problems found in DA1. By relying on suitable theories as a foundation, the Converge-VRD has a strong basis and systematic way to understand the situation in more interrelated concepts and propositions that will help to explain and predict the solution. Furthermore, based on the theories, the research was able to prescribe the theorizing solution that matched the problem. By prescribing the process of embedding the integrated kernel theories into visualizaton perspectives, the design theory explains why it is important to have three principles for facilitating the Collaborative-CCA process. Furthermore, the design theories applied and extend the kernel theories for being more suitable for visualization use. In this way, Converge-VRD as the design theory is much more readily adoptable in the future visualization development.

c Design Artifact 3 (DA3) – The Evaluation Findings.

The Converge-VRD evaluation shows the positive findings as summarized in Table 6.9 (conclusion in chapter 6). Basically three main findings from the research had justified the capabilities of Converge-VRD to:

- Centralize and externalize the Collaborative-CCA guidelines,
- Bring an awareness about the convergence
- Handle an emergent patterns.

The evaluation found the significance of Converge-VRD Principle 1 helps to develop centralized mental model and bring clarities during the performance of the Collaborative-CCA process. The approach of KV and IV provided some foundations to inform the design of Collaborative CCA visualizations. It has the potential to bring an understanding of the knowledge context as used in KV to complement the formation of visual representation structures in IV. Moreover, the evaluation also found the usefulness of Converge-VRD Principle 2 to facilitate the lack of understanding about the importance of convergence. By relying on general systems thinking provide a more systemic view of the interconnections between various elements, hence better supporting the users to gain some awareness about the convergence. However, the research also discovered certain elements for Converge-VRD Principle 2 during the evaluation:

- Even though the higher level of visual structure seemed untouched during the Collaborative-CCA process, it is useful to guide the how knowledge and let the users have the similarity points to consider during the collaborative-CCA process

- The principle 2 was able to bring an awareness about the convergence by letting the users clear about the main driver and able to see and draw the interconnection between various elements but it doesn't guarantee that the Collaborative-CCA process is able to come out with the valuable converge-integrative solution all the time.

Finally, Converge-VRD Principle 3 is capable to handle and develop growth of information emergent evolvement. The evaluation showed the second order cybernetics theories are able to frame the idea of open ended visual representations. They provides dynamisms and flexibility to knowledge construction and extension for collective mental model development among users. These evaluation findings helped to justify the relevancy of Converge-VRD to handle the Collaborative-CCA process through relevance cycle by returning Converge-VRD into the Collaborative-CCA environment for the evaluation. Hence, the evaluation has justified the effectiveness of Converge-VRD to facilitate the Collaborative-CCA process.

7.2.2 Contribution 2 – Design Process to Guide Specific Use Visualization.

Corresponding with LR in section 2.7, the thorough and integrative design process for specific use visualization yet lack in the research. The suitable methodology has been the challenge since the findings from LR indicated that: i) generally, there is inadequate of visual design process, ii) if there is so, it is focused more on functional and operational use (e.g visual mapping, operating steps and taxonomies) and iii) there is a lack of rationales for design decision. Furthermore, the specific context visualization must go beyond the users and dig more about their context of use and the activities involved - these will lead to the rationales of any design solution and returning the design solution into the real settings for the context of use will justify the relevancy of it. Therefore in this section, we intend to highlight the research contributions that offer the potential guidelines for these shortcomings. One of the advantages of using DSRM is the flexibility for the phases to be combined with other appropriate methods. The encouragement to adapt other theories and methods is what needed most since we need the research from other areas and fields to help us. By having DSRM as the basic guidelines and with the combination of other knowledge base, the research found the suitability of the research design process to guide the specific use visualization through human-activity centric approach. Even though the research focused on Collaborative-CCA context of use but we believe through these understanding can help to guide the process design for other context of use as shown in Figure 7.4.

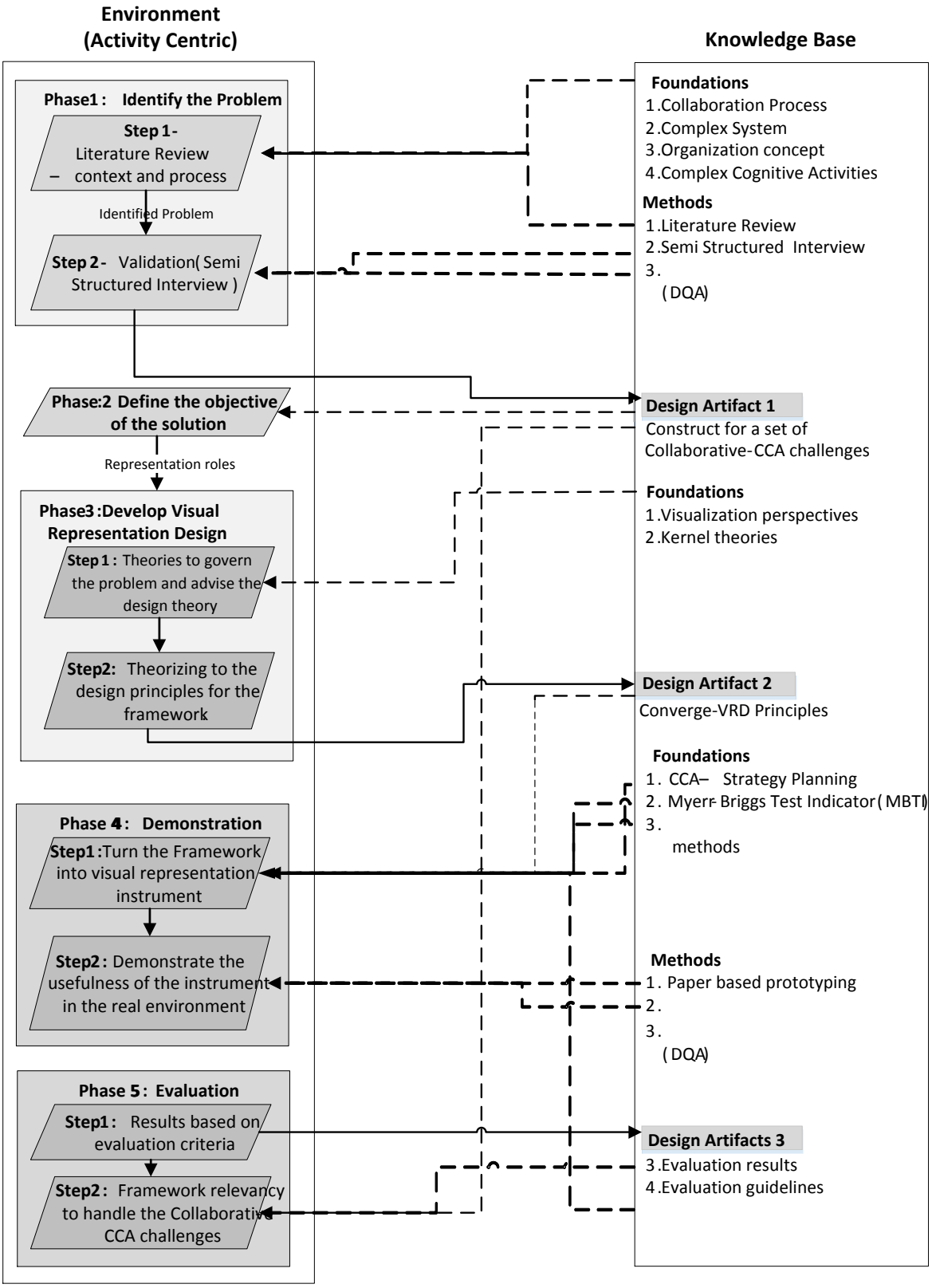


Figure 7.4 Design Process for the Specific Use Visualization

There are basically five important phases of the design process that aim for three design artifacts and there are interconnections between these phases and steps.

Generally, the visualization design solution as the main outcome from the research will be supported by the identified challenges and furthermore the evaluation will justify the effectiveness of the solution. That is why, it is important to understand that DAI will be reflected from visualization perspectives to provide rationales to see the clearer roles for visualization solution. Then the visualization solution as the DA2 will be evaluated in to justify its relevancy to handle the challenges identified in DA1. The five of design process phases will be described according to their activities in the next paragraph.

In addition to the evaluation design process, the research sense the potential of the evaluation process to guide the visualization community especially to evaluate visualization for specific use and natural settings perspectives. This is because, evaluation for visualization is usually based on experiments and quantitative approach (Lam et al. 2011). Here, we bring some cornerstone to evaluate the visualization in more natural settings and qualitative approach. Furthermore, the evaluation emphasized the effectiveness of visualization design by accessing its usefulness to handle the identified challenges. By offering a set of evaluation recommendations, this research aimed to improve the experience for the visualization community to evaluate in a more flexible, dynamic and intuitive way. Hence, focus group observation brings balance between the environmental control and context's natural settings. Furthermore, it will properly guide the evaluation by explaining the evaluation criteria, sampling strategy and participation, focus group tasks and settings and finally data management and analysis as summarized in Table 7.1

Table 7.1 The Evaluation Guidelines

No.	Scope of guidelines	Descriptions
1	Evaluation Design	The evaluation method used is the Focus Group Observation This evaluation is aimed to understand the practical usefulness of the visualization design theories in facilitating the context of use. In order to do that, the evaluation need to observe the interactive collective process of the users while performing their activities
No.	**Scope of guidelines**	**Descriptions**
2	Evaluation criteria	Unit of Analysis is the interactivity between the users and visual representation in the natural settings of the collaborative-CCA

		phenomenon. Evalution criteria for effectiveness is the reflection from the identified challenges (Hevner, 2007)
3	Sampling strategy and participation	The evaluation used purposeful sampling strategy (Patton, 1990). Through an iterative process, the research loosened the criteria of sampling because the evaluation intends to observe the activities during the interactivity process in a natural way. Thus the focus group observation seems to be more flexible and open ended to adapt the real participants and activities' necessities. Due to the consideration of intensity and richness of qualitative data collection, analysis and interpretation, the research found three (3) groups have been sufficient to show the effectiveness of visual design.
4	Focus Group tasks and settings,	Before the Focus Group Observation • Gather the group context of use. • Demonstrate the visual design theories into visual representation instruments that can be used during the focus group observation. Accessing the usefulness criteria during the observation • Visual representation instruments as the probe during the focus group. • The participants in the group of 4-6 people were gathered in the meeting room. • The group were to discuss as in a normal meeting or discussion group as long as they would refer and utilize the provided visual representation. • The focus group lasted around 90-120 minutes. • The research observed and recorded the interactivity as evidence on how the visual representation would be able to facilitate the context of use.
5	Data management and analysis.	Three types of data-capturing device to collect, store and manage the data: • Audio recording of the discussions among the users. • Video recording to capture the human interactions not easily recorded using audio. • Annotation in the visual representation application. Deductive Qualitative Analysis (DQA) • The thematic analysis process based on open coding was carried out as usual, but the codes for a theme had been assigned according to the unit of data analysis and evaluation criteria as mentioned in the second row above. • Transcribed the relevant verbal expressions. • Quoted any appropriate from transcriptions. Each quotation would then be grouped according to identified themes/subthemes. • Triangulated the interactivity from video observations and contents records in the visual structure to complement the identified quotation /subtheme /theme

This research highlighted the specific context visualization design process as a potential contribution to the visualization field. By having DSRM as a backbone in research design, we found it is useful and benefit us throughout the design process. The capabilities of DSRM to play the directive and macro-manage role let the visualization design process guided on the right path and yet at the same time is able

to give freedom in designing visualization according to its function, quality and context. The balance between guidance and freedom is essential in a visualization process design. Too rigid on the guidance will kill the creativity, ideas and exploration of visual design. However, if it is too loose, then we will come back to square one – no comprehensive guidelines for visualization design process.

Furthermore, this kind of design process give the new perspective a better understanding of the users and their activities. Before this, HCD used the concept of asking users what they wanted. The research found this kind of concept burdened the users and was somehow misleading because the users sometimes didnt know what they want, furthermore, what has been described as what they wanted is actually based on their desire, not on what they needed. Thus, by embedding ACD in understanding the context of use, the research was able to identify the activities, its sequential and the challenges faced during executing the activities in a more consistent manner. From here, the designer or the developer should be able to propose an appropriate solution based on more consistent rationales.

7.3 LIMITATIONS AND CHALLENGES

The research has been worried if the sampling sizes for the data collection is not capable to represent the real phenomenon of Collaborative-CCA. However after consulting with the qualitative researcher and a few journal - (Gilgun, 2010), Suri (2011), March & Smith (1995) and Hevner (2011), we are convinced that the sampling sizes are limited yet sufficient for this particular research because:

- The research is a pragmatic mode, as the data collection is not the prime element for the main contribution. Since this research is aiming for a visual design solution, the sampling for the data collection is not aiming for theory building but instead the data collection is for validating and expanding the findings from the LR.

- By analysing through DQA, the data is sufficient because we already set the criteria on the data collection. Thus, the instances from the data are meant for supporting the assigned themes.

Furthermore, due to building up some foundations for collaborative-CCA visualization, the research weighted more on design with theoretical concept (design theory and principles development), hence the research evaluated and accepted these theories based on sufficiency level. Due to these weightage, the research put some limitation during evaluation in term of the CCA domain and its sampling size. Nevertheless, in order to fill in some shortcomings of 'why' and 'how' from LR, the research concern for rationales on design outcomes and rigorous on design process. Thus, the research weight more on relevancy and rigor cycle for an effective (useful) design theories and credible design process.

7.4 FUTURE RESEARCH DIRECTIONS

Due to the previous limitation, in the future - with the goal of ultimately enhancing and strengthening these design theories, the research intend to have more rigorous evaluation and testing to see how well these design theories reflect the observations of reality. As an example, the improvement of the evaluation can be done through the evaluation by increasing the sampling size, testing in different domains of CCA, developing cross case analysis between each domain, executing the visual representation instruments in the varieties of technological platform and iterating multiple times for the evaluation and design process. Furthermore, by focusing on specific CCA domain, the research can develop more determine goal, tasks and actions towards more empirical and scientific evaluation. With the enhancement of evaluation sampling, domain and iteration - the research can further strengthen Converge-VRD through the design cycle.

Moreover, the research has discovered the potential of IV and its related fields (e.g. data visualization, scientific visualization, visual analytics and data journalism) in providing the visual structure for specific use visualization (in the case of this research, we concentrated on the visualization for Collaborative-CCA usage). From

here, the research found the tremendous of visualization techniques, methods and tools has been developed to enhance the human cognitive in understanding information and believe that with some cornerstone, these current visualizations can also bring benefit to facilitate any specific context of use. The categorization through taxonomies, mapping and cataloguing are among the techniques that can be use to utilize the current visualization structures for Collaborative-CCA usage.

While this thesis is focus to understand the 'why' questions for each of the design theory and principles for Collaborative-CCA context of use. Then for future direction, the research intend to explore about the 'how elements' of Converge-VRD to be practical and consult these current visualizations. There is a need to further investigate about the 'how' questions in order to bring the Converge-VRD design theories into design elements that applicable for current visualizations with varieties of technological aspects. By further investigate the applicable of Converge-VRD into the design elements, hence is potentially complement and improve current visualization techniques, methods and tools. To be more specific, the research intend to further explore the analytical part since its complementing the synthesizing part. Furthermore, this is what the future is looking for and we believe the extension from this research can bring benefit to complement Business Intelligence, Visual Analytics and Big Data (John et al 2012) in more comprehensive and effective way especially to facilitate the Collaborative-CCA use in the organization.

Finally, the research intends to dig further about the findings from NCA that might be related to the Collaborative-CCA Process. Personalization and multisources of information contribute to a better understanding of Collaborative-CCA challenges and the capabilities of Converge-VRD to foster innovative thinking, thus digging these elements further might bring benefits toward a better visualization design.

a Personalization

Personalization is meant to tailor the solution to accommodate specific individual, group or segments of individuals. By identifying the users' behaviours, cultures or histories, the solution is aimed to improve the users' satisfaction by increasing their

acceptance. Due to the interviews, the research found the dependency of the roles of the chairperson or secretariat to achieve higher quality outcomes and performances during the Collaborative-CCA process. The roles, knowledge and skills of the users especially the decision makers can make a difference during the process. In contrast, they also mentioned the passive mode of certain users that contributed less during the Collaborative-CCA process.

b Multisources of information

The extracting process is subjected to the complexity of the requirements. The process of gaining the information retrieval under complex circumstances is more difficult because the users are actually accessing from the variety of sources. It covers multiple points and the depth of the information extractions that may lead the users to lose thread of an issue. Therefore, the users need to be guided through the extracting process. The trail to the relevant sources is important so that will eliminate the possibility of lost or missed valuable information while digging the contents. In this case, the process of extracting often produces a large volume of content of varying relevance, across multiple levels of abstraction and of varying granularity. Besides that, the manual searching process from all the tools and sources is very time and energy consuming. A lot of effort is needed to read, ask people, observe, understand, relate and finally have the whole picture for any subject of interest. Furthermore, there are different coverage of information between the experts and the decision maker as a group. The coverage for experts are mostly under the job scope boundary or similar expertise field. It is also found that experts are gaining the details more than the abstract. Meanwhile, decision makers omit the boundary both on the job scope and the organization in which need abstracts more than details.

c Foster Innovative Thinking

As observed, the visual structure was capable to guide and organize the new emergent element to be assimilated with the previous content. This explicit assimilation brings further clarities about the interconnection and construction of new information in the representation space. As a result, the users were able to grasp the real understanding of

how and why for each of the cognitive interpretations. According to Keeley et al (2013), understanding the real question of ‘how’ and ‘why’ is the key to spark valuable innovation. From here, the users were able to pull pieces of the puzzle together across the various interconnections of elements to come out with practical solutions and high value of outcomes for the organization (Kim & Mauborgne, 2005).

7.5 FINAL REMARKS

Due to specific context-use of visualization, in this case is Collaborative-CCA context, the research is concerned towards an effective visualization design. This thesis addressed the aims and answered the research questions. The research has identified 3 DA as research outcomes based on each of the RO in which these outcomes contribute to an effective of visualization design solution for the Collaborative-CCA process.

The thesis emphasized that the visualization should be useful to the users, thus identifying the challenges and considering these challenges as the decision rationales during development and evaluation of the visualization design solution is essential. From challenges understanding, the research found the needs to facilitate the increased of information complexities due to multiple participants to achieve shared understanding. Furthermore, the emergence of information lead to convergence and evolvement of knowledge construction during Collaborative-CCA process. In conjunction with that, the visual representation roles is not only to reduce and control the information, furthermore, it must be able to facilitate, shape and alter the users’ mental space and coordinate towards the higher level of information’s understanding. Finally, by providing the answer for ‘why’ and ‘how’ human users need and been supported by visualization through the relevancy cycle has justified the effectiveness of the Converge-VRD to handle the Collaborative-CCA challenges. Moreover, the thesis found the suitability of the research design process to guide the specific use visualization through human-activity centric approach. Even though the research focused on Collaborative-CCA context of use but we believe the same process design can help to guide other context of specific use for visualization designs.

REFERENCES

Adnan, W. A. W., Daud, N. G. N. & Noor, N. L. M. 2008. Expressive information visualization taxonomy for decision support environment. *Third International Conference on Convergence and Hybrid Information Technology (ICCIT'08),* 88-93.

Agrawala, M., Li, W. and Berthouzoz, F. 2011. Design Principles for Visual Communication. *Communications of the ACM* 54(4): 60-69.

Akrani, G. 2010. Decision Making Process In Management - Problem Solving. *Study Notes in Education and Management*.

Albers, M. 2010. Usability and Information Relationship: Considering content relationship when testing complex information. in *Usability of Complex Information Systems: Evaluation of User Interaction*. Albers, M., Still, B. (Eds.). 109-132, CRC press.

Albers, M. 2015. Human-Information Interaction with Complex Information for Decision Making. *Informatics* 2(2): 4-19.

Albers, M. J. 2008. Human-information interaction. *Proceedings of the 26th annual ACM International Conference on Design of Communication,* 117-124.

Albers, M.J. 2004. *Communication of Complex Information: User Goals and Information Needs for Dynamic Web Information;* NJ USA, 2004.

Alturki, A., Gable, G. G., & Bandara, W. 2011. A design science research roadmap. In *Service-Oriented Perspectives in Design Science Research*. Jain, H., Sinha, A. P. & Vitharana, P. (Eds.). 107-123, Springer Berlin Heidelberg.

Aman, H., Irani, P. and Amini, F., 2014. Revisiting crisis maps with geo-temporal tag visualization. *IEEE Pacific Visualization Symposium (PacificVis),* 177-184.

Amar, R. & Stasko, J. 2004. BEST PAPER: A knowledge task-based framework for design and evaluation of information visualizations. *Proceedings of the 2004 IEEE Symposium on Information Visualization,* 143-150.

Amar, R., Eagan, J., and Stasko, J., 2005. Low-level components of analytic activity in information visualization. *Proceedings of the 2005 IEEE Symposium on Information Visualization,* 111-117.

Bar-Yam, Y. 1997. *Dynamics of Complex Systems*. Reading Vol 213. Addison-Wesley.

Bar-Yam, Y. (2002). General Features of Complex Systems. in *Encyclopedia of Life Support Systems (EOLSS),* London: EOLSS Publishers Oxford.

Bashir, R. N., Qadri, S., Saleem, R. M., Naeem, M., & Ghafoor, Y. 2014. Human Computer Interaction (HCI) in Ubiquitous Computing. *International Journal of Innovation and Applied Studies* 9(2), 534-541.

Bates, M. J., 2005. Information and knowledge : An evolutionary framework for information science. *Information Research*, 10(4).

Bertschi, S. 2009. Knowledge Visualization and Business Analysis: Meaning as Media. *IEEE International Conference Information Visualization* 13: 480–485

Bertschi, S., Bresciani, S., Crawford, T., Goebel, R., Kienreich, W., Lindner, M., Sabol, V. & Moere, A.V. 2011.What is knowledge visualization? Perspectives on an emerging discipline. *Proceedings of the 2011 IEEE Symposium on International Conference of Information Visualisation*, 329-336.

Beyond the Podium: Delivering Training and Performance to a Digital World. http://www.jbp.com. [25 October 2014].

Bischof, N., Comi, A., & Eppler, M. J. 2011. Knowledge Visualization in Qualitative Methods - Or How Can I See What I Say*? IEEE International Conference Information Visualization* 15, 371–376.

Bresciani, S., Blackwell, A. F. & Eppler, M. 2008. A Collaborative Dimensions Framework : Understanding the Mediating Role of Conceptual Visualizations in Collaborative Knowledge Work. *Proceedings of the 41st Hawaii International Conference on System Sciences*, 364-374.

Bresciani, S., & Eppler, M. J. 2010. Choosing Knowledge Visualizations to Augment Cognition: The Managers' View. *IEEE International Conference Information Visualization* 14, 355–360.

Bresciani, S.; Eppler, J. 2011. The benefits of synchronous collaborative information visualization: evidence from an experimental evaluation, *IEEE Transaction Visualization Computer Graphic* 15, 1073–1080.

Brey, P. 2005. The epistemology and ontology of human-computer interaction. *Minds and Machines* 15(3-4): 383-398.

Briggs, R. O., Kolfschoten, G., Vreede, G. J. D., Albrecht, C., Dean, D. R., & Lukosch, S. 2009. A seven-layer model of collaboration: Separation of concerns for designers of collaboration systems. *ICIS 2009 Proceedings* 26.

Burkhard, R. A. & Eppler, J. 2004. Knowledge Visualization towards a New Discipline and its Fields of Application. *USI Research Note* 2.

Burkhard, R. A. 2004. Learning from architects: the difference between knowledge visualization and information visualization. *IEEE 8th International Conference on Information Visualisation*, 519-524

Burkhard, R. A. 2005b. Towards a framework and a model for knowledge visualization: Synergies between information and knowledge visualization. in

Knowledge visualization and information visualization: Searching for synergies. Tergan, S.O. & Keller, T. (Eds.). 238-255, Springer Heidelberg.

Burkhard, R. A. 2005a. Knowledge Visualization: The Use of Complementary Visual Representations for the Transfer of Knowledge: a Model, a Framework, and Four New Approaches. Doctoral Dissertation, Swiss Federal Institute for Environmental Science and Technology.

Business dictionary, http://www.businessdictionary.com [3 March 2012]

Byrne, D. (2014). Thoughts on a pedagogy of complexity. *Complicity*, *11*(2), 40.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J. & Eskridge, T. 2004. CmapTools: A knowledge modeling and sharing environment. in *Knowledge visualization and information visualization: Searching for synergies.* Tergan, S.O. & Keller, T. (Eds.). 185-204, Springer Verlag Berlin Heidelberg.

Carbone E. T. 2010. *Using Qualitative & Quantitative Research Methods to Answer your Research Questions.* Presentation of University of Massachusetts Medical School.

Carcary, M. 2009a. The research audit trial–enhancing trustworthiness in qualitative inquiry. *The electronic journal of business research methods* 7(1): 11-24.

Carcary, M. 2009b. Evaluating Qualitative Research–Implementing the Research Audit Trail. *8th European Conference on Research Methodology for Business and Management Studies* 94.

Carcary, M. 2011. Evidence analysis using CAQDAS: Insights from a qualitative researcher. *The Electronic Journal of Business Research Methods* 9(1): 10-24.

Card, S. K., & Mackinlay, J. 1997. The structure of the information visualization design space. *IEEE Symposium on Proceedings Information Visualization*, 92-99.

Card, S. K., Mackinlay, J. & D., Schneiderman, B. 1999. Information Visualization: Using Vision To Think. San Francisco: Morgan Kaufmann.

Chen, C., 2005. Top 10 unsolved information visualization problems. *IEEE Computer Graphic Application* 25(4): 12–6.

Chen, M. & Floridi, L. 2013. *An analysis of information visualisation: in Synthese.* Chen, M. & Floridi, L (Eds.). 190(16): 3421-3438, Springer.

Chi, E. H. 2000. A taxonomy of visualization techniques using the data state reference model. *IEEE Symposium on InfoVis 2000 Information Visualization*, 69-75.

Comi A. & Eppler. M. J. 2011. Visual representations as carriers and symbols of organizational knowledge. *Proccedings of 11th International Conference on Knowledge Management and Knowledge Technologies (l-KNOW'l1).*

Comi, A. & Eppler, M. J. 2010. Challenges and Solutions for Knowledge Sharing in Inter-Organizational Teams: First Experimental Results on the Positive Impact of Visualization. *Proccedings of 10th International Conference on Knowledge Management and Knowledge Technologies (l-KNOW'l0).*

Complexity learning. http://complexityacademy.io [3 january 2014]

Corbin, J. M., & Strauss, A. (1990). Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative Sociology* 13(1): 3-21.

Corning, P. A. 2002. The re-emergence of "emergence": A venerable concept in search of a theory. *Complexity* 7(6): 18-30.

Covey, S. 1989. The Seven Habits of Effective People. *New York: Simon*.

Craft, B., & Cairns, P. 2005. Beyond guidelines: what can we learn from the visual information seeking mantra? *IEEE ninth International Conference of Information Visualisation*, 110-118.

Craft, B., & Cairns, P. 2008. Directions for Methodological research in information visualization. *IEEE 12th International Conference of Information Visualisation,* 44-50.

Creswell, J. W., Plano Clark, V. L., Gutmann, M. L., & Hanson, W. E. 2003. Advanced mixed methods research designs. *Handbook of Mixed Methods in Social and Behavioral Research*, 209-240.

Creswell, J., 2009. *Research design: Qualitative, Quantitative, and Mixed Methods Approaches*. SAGE Publications Incorporated.

David G. 2009. The Convergence between For-Profit and Nonprofit Hospitals in the United States. *International Journal Health Care Finance Econ* 9(4): 403–428.

Dickie, M., 2000. *Experimenting on classroom experiments: Do They Increase Learning in Introductory Microeconomics*. University of Southern Mississippi.

Dillenbourg, P., & Betrancourt, M. 2006. Collaboration Load. in *Dealing with Complexity in Learning Environments*. Elen, J. & Clark R.E. (Eds.). 142–163, Elsevier

Dillon, K. M., Talbot, P. J., & Hillis, W. D. 2005. Knowledge Visualization: Redesigning the Human-Computer Interface. *Technology Review Journal* 13(1): 37–55.

Drocourt, Y., Borgo, R., Scharrer, K., Murray, T., Bevan, S. I., & Chen, M. 2011. Temporal Visualization of Boundary-based Geo-information Using Radial Projection. *Computer Graphics Forum* 30(3): 981-990.

Elias, M & Bezerianos, A. 2011. Exploration Views: understanding dashboard creation & customization for visualization novices. *13th Proceedings of*

INTERACT Conference (IFIP TC13) on Human-Computer Interaction 4, 274-291.

Elias, M & Bezerianos, A. 2012. Annotating BI Visualization Dashboards: Needs & Challenges. *In Proceedings of ACM SIGCHI Conference on Human Factors in Computing Systems (CHI 2012)*, 1641-1650.

Elliott, R. & Timulak, L. 2005. Descriptive and interpretive approaches to qualitative research. in a Handbook of Research Methods for Clinical and Health Psychology. Miles, J. & Gilbert, P. (Eds.). 147-159, Oxford University Press.

Engelbrecht, L., Botha,A. & Alberts, R. 2014 Designing the visualization of information. International Journal of Image and Graphics, 15(02):

Eppler M. J., A. Linda, Adorisiom M. & J. Mengis, 2004. Communicating to See (and Keep) the Big Picture. A Challenge in the Interaction of Managers and Specialist, in: *ICA Working Paper #3/2004,* University of Lugano, Switzealand.

Eppler, M. J. & Bresciani, S. 2013. Visualization in management: From communication to collaboration. A response to Zhang. *Journal of Visual Languages & Computing* 24(2): 146–149.

Eppler, M. J. & Burkhard, R. A. 2007. Visual representations in knowledge management: framework and cases. *Journal of Knowledge Management* 11(4): 112-122.

Eppler, M. J. 2006a. *The Concept of Knowledge Communication and Its Relevance to Management.* USI Research Note July, 1–12. Universiti St Gallen, Switzealand.

Eppler, M. J. 2006b. *Knowledge Integration in Face-to-Face Communication and the Moderating Effect of a Collaborative Visualization Tool.* USI Research Note August, 1-93. Universiti St Gallen, Switzealand.

Eppler, M. J. 2011a. Visual Collaboration: Improving Meetings & Knowledge Sharing through Interactive Visualization Summary: *Visual Collaboration* 1, 1–8.

Eppler, M. J. 2012. 10 years of Knowledge-Communication. Results, Insights and Perspectives, http://issuu.com/mcminstitute/docs [12 Mac 2013]

Eppler, M. J. and Burkhard, R. A. 2005. Knowledge visualization. in *Encyclopedia of Knowledge Management*. Schwartz, D. G. (eds.). 551-560, IGI Global.

Eppler, M. J., Bresciani, S. & Hoffmann, F. 2011b. New Business Models Through Collaborative Idea Generation. *International Journal of Innovation Management* 15(06): 1323–1341.

Eppler, M. J., Mengis, J. & Bresciani, S. 2008. Seven Types of Visual Ambiguity: On the Merits and Risks of Multiple Interpretations of Collaborative Visualizations. *IEEE International Conference of Information Visualization* 12, 391-396.

Ericsson, K. A. & Hastie, R. 1994. Contemporary approaches to the study of thinking and problem solving. in *Thinking and Problem Solving*. Sternberg, R. J. (Ed.). 37-79, Academic Press.

Fast, K. V. & Sedig, K. 2010. Interaction and the epistemic potential of digital libraries. *International Journal on Digital Libraries* 11(3): 169-207.

Flensburg, P. 2009. An enhanced communication model. *The International Journal of Digital Accounting Research* 9(15): 31-43.

Floridi, L. 2010. The philosophy of information: Ten years later. *Metaphilosophy* 41(3), 402-419.

Funke, J. 2010. Complex Problem Solving: A Case for Complex Cognition? *Cognitive Processing* 11, 133-42.

Gabriel, D. Inductive and deductive approaches to research. Research Methods. http://deborahgabriel.com/2013/03/17/inductive-and-deductive-approaches-to-research [15 September 2014]

Gao, S., & Low, S. P. (2013). The Toyota Way problem-solving model: lessons for large Chinese construction firms. *International Journal of Construction Management* 13(1): 79-103.

Gardner, W, L. & Martinko, 1996. M. J. Using the Myers-Briggs Type Indicator to Study Managers: A Literature Review and Research Agenda. *Journal of Management* 22(1): 45-83.

Geerts, G. L. 2011. A design science research methodology and its application to accounting information systems research. *International Journal of Accounting Information Systems* 12(2): 142-151.

Gilgun, J. F. 2005. Qualitative research and family psychology. *Journal of family psychology*, 19(1): 40.

Gilgun, J. F. 2010. A Primer on Deductive Qualitative Analysis as Theory Testing and Theory Development. *Current Issues in Qualitative Research* 1(3).

Gilgun, J. F. 2011. Coding in deductive qualitative analysis. *Current Issues in Qualitative Research: An Occasional Publication for Field Researchers from a Variety of Disciplines*, 2(1): 1-4.

Glouberman, S. & Zimmerman, B. 2002. *Complicated and complex systems: what would successful reform of Medicare look like?* Toronto: Commission on the Future of Health Care in Canada.

Goldfrey-Smith, P. 2002. Environmental Complexity and the Evolution of Cognition. *The Evolution of Intelligence*, 233-249.

Goldkuhl, G. 2004. Design theories in information systems-a need for multi-grounding. *Journal of Information Technology Theory and Application (JITTA)* 6(2): 59.

Goswami, B. 2004. *The Human Fabric: Unleashing the Power of Core Energy in Everyone*, Aviri Publishing.

Greenbank, P. 2003. The role of values in educational research: The case for reflexivity. *British Educational Research Journal* 29(6): 791-801.

Gregor, S. & Hevner, A. R. 2013. Positioning and Presenting Design Science Research for Maximum Impact. *MIS Quarterly* 37(2): 337-355.

Gregor, S. & Jones, D. 2007. The anatomy of a design theory. *Journal of the Association for Information Systems* 8(5): 312.

Greiff, S., Wüstenberg, S., Molnár, G., Fischer, A., Funke, J. & Csapó, B. 2013. Complex Problem Solving in Educational Contexts - Something beyond Concept, Assessment, Measurement Invariance, and Construct Validity. *Journal of Educational Psychology* 105(2): 364.

Heer, J. & Agrawala, M. 2008. Design considerations for Collaborative Visual Analytics. *Information Visualization* 7(1): 49-62.

Hevner, A. & Chatterjee, S. 2010. *Design research in information systems: theory and practice* (Vol. 22). Springer Science & Business Media.

Hevner, A. R. 2007. A three cycle view of design science research. *Scandinavian Journal of Information Systems 19*(2): 4-7.

Hevner, R., March, S. T., Park, J. & Ram, S. 2004. Design Science in Information Systems Research. *MIS Quarterly* 28(1): 75-105.

Hodgson, A. 2009. Decision Integrity and Second Order Cybernetics. in Theory in Management: Tools, Views and Advancements. Wallis, S. E. (Ed.). 52-74, Information Science Reference.

Hoque, F., & Baer, D. 2014. *Everything Connects: How to Transform and Lead in the Age of Creativity, Innovation, and Sustainability.* McGraw Hill Professional.

Hornbæk, K. & Hertzum, M. 2011. The notion of overview in information visualization. *International Journal of Human-Computer Studies* 69(7): 509-525.

Huang, W. 2014. Handbook of Human Centric Visualization. Springer New York.

Hundhausen, C. D. 2004. Using End User Visualization Environments to Mediate Conversations : A " Communicative Dimensions ". *Journal of Visual Languages and Computing* 16(3): 158–185.

Hundhausen, C. D. 2014. Evaluating Visualization Environments: Cognitive, Social, and Cultural Perspectives. in *Handbook of Human Centric Visualization.* Huang, W. (Ed.). 115-145, Springer New York.

Hutchins, E. 2000. Distributed Cognition. *International Encyclopedia of the Social and Behavioral Sciences. Elsevier Science*.

Infovis. 2012. Resources of Information Visualization. http://www.infovis.org [1 Jun 2012]

Isenberg, P., Elmqvist, N., Scholtz, J., Cernea, D., Ma, K. L. & Hagen, H. 2011. Collaborative Visualization:Definition, Challenges, and Research Agenda. *Information Visualization Journal (IVS), Special Issue on Information Visualization State of the Field and New Research Direction* 10(4): 310–326.

John, H., Sallam, R. L. & Richardson, L. J. 2012. Magic Quadrant for business intelligence platforms. *Gartner for Business Leaders.*

Johnson, J. 2010. Embracing design in complexity. In *Embracing Complexity in Design.* Alexiou, K. & Johnson, J. (Eds.). 193–203, Routledge.

Keeley, L., Walters, H., Pikkel, R., & Quinn, B., 2013. Ten Types of Innovation: The Discipline of Building Breakthroughs. John Wiley & Sons.

Keller, T. & Grimm, M. 2005. The Impact of Dimensionality and Color Coding of Information Visualizations on Knowledge Acquisition. in *Knowledge visualization and information visualization: Searching for synergies.* Tergan, S.O. & Keller, T. (Eds.). 167-184, Springer Heidelberg.

Keller, T., & Tergan, S. O. (2005). Visualizing knowledge and information: An introduction. in *Knowledge visualization and information visualization: Searching for synergies.* Tergan, S.O. & Keller, T. (Eds.). pp. 1-23, Springer Berlin Heidelberg.

Kim, W. C. & Mauborgne, R. 2005. *Blue Ocean Strategy, How to Create Uncontested Market Space and Make the Competition Irrelevant*. Harvard Business Review Press.

Kirsh, D. & Maglio, P. 1994. On distinguishing Epistemic from Pragmatic Action. *Cognitive Science*, *18*(4), 513-549.

Kirsh, D. 2006. Distributed cognition: A methodological note. *Pragmatics & Cognition* 14(2): 249-262.

Knauff, M. & Wolf, A. G. 2010. Complex Cognition: The Science of Human Reasoning, Problem-Solving and Decision-Making. *Cognitive processing* 11(2): 99-102.

Kolfschoten, G. L. & Brazier, F. 2012. Cognitive Load in Collaboration-Convergence. *45th Hawaii International Conference on System Sciences*, 129–138.

Kolfschoten, G. L. 2012. Introduction to the 'Cognitive Perspectives on Collaboration' Minitrack. *38th Euromicro Conference Software Engineering Advance Application.*

Krathwohl, D. R. 2002. A revision of Bloom's taxonomy: An overview. *Theory into Practice* 41(4): 212-218.

Kuechler, B. & Vaishnavi, V. 2008. On theory development in design science research: anatomy of a research project. *European Journal of Information Systems* 17(5): 489-504.

Kuechler, B. & Vaishnavi, V. 2011. Promoting relevance in IS research: An informing system for design science research. *Informing science: The international journal of an emerging transdiscipline* 14(1): 125-138.

Ladyman, J., Lambert, J. & Wiesner, K. 2013. What is a complex system? *European Journal for Philosophy of Science* 3(1): 33-67.

Lam H., Bertini, E., Isenberg, P., Plaisant, C. & Carpendale, S. 2011. Seven Guiding Scenarios for Information Visualization Evaluation Seven Guiding Scenarios for Information Visualization Evaluation. *TechReport 2011-992-04.* University of Calgary.

Lengler, R. & Eppler, M. J. 2007. Towards A Periodic Table of Visualization Methods for Management. *Proceedings of the IASTED International Conference on Graphics and Visualization in Engineering (GVE 2007)*, 83–88.

Liang, H. N. & Sedig, K. 2010. Role of Interaction in Enhancing the Epistemic Utility of 3D Mathematical Visualizations. *International Journal of Computers for Mathematical Learning* 15(3): 191-224.

Liedtka, J. & Ogilvie, T. 2011. *Designing for Growth.* New York: Columbia Business School Publishing.

Liedtka, J. 2014. Perspective: Linking Design Thinking with Innovation Outcomes through Cognitive Bias Reduction. *Journal of Product Innovation Management* 32(6), 925-938.

Lima, M. 2011. *Visual Complexity: Mapping Patterns of Information.* Marjorie Weiser Milas Fund. *Princeton Architectural Press*

Liu, Z. & Stasko, J. 2010. Mental models, visual reasoning and interaction in information visualization: A top-down perspective. *IEEE Transactions on Visualization and Computer Graphics* 16(6): 999-1008.

Liu, Z., Nersessian, N. & Stasko, J. 2008. Distributed Cognition as a Theoretical Framework for Information Visualization. *IEEE Transactions on Visualization and Computer Graphics* 14(6); 1173–80.

March, S. T. & Smith, G. F. 1995. Design and Natural Science Research on Information Technology. *Decision Support Systems* 15(4): 251-266.

Markus, M. L., Majchrzak, A. & Gasser, L. 2002. A Design Theory for Systems that Support Emergent Knowledge Processes. *MIS quarterly*, 179-212.

Masud, L., Valsecchi, F., Ciuccarelli, P., Ricci, D. & Caviglia, G. 2010. From Data to Knowledge-Visualizations as Transformation Processes Within the Data-Information-Knowledge Continuum. *IEEE 14th International Conference* of *Information Visualization (IV),* 445-449.

Mengis J. 2007a. Integrating Knowledge through Communication-the Case of Experts and Decision Makers. Proceedings of the International Conference on Organizational Knowledge, Learning and Capabilities (OKLC) 44, 699–720.

Mengis, J. & Eppler, M. J. 2006. Knowledge Integration in Face-to-Face Communication and the Moderating Effect of a Collaborative Visualization Tool, Universita'della Svizzera, Italiana.

Mengis, J. & Eppler, M. J. 2007. *Integrating Knowledge through Communication: an Analysis of Expert-Decision Maker Interactions.* Institute of Corporate Communication.

Mengis, J. & Eppler, M. J. 2008. Understanding and Managing Conversations from a Knowledge Perspective: an Analysis of the Roles and Rules of Face-to-Face Conversations in Organizations. *Organization Studies* 29(10): 1287-1313.

Mengis, J. 2007b. Integrating Knowledge through Communication: An analysis of Expert-Decision Maker Interactions. PhD Dissertation. University of Lugano.

Mertens, D. M. 2003. Mixed Methods and the Politics of Human Research: The Transformative-Emancipatory Perspective. *Handbook of Mixed Methods in Social and Behavioral Research*, 135-164.

Meyer, R. 2009. Knowledge Visualization. *Trends in Media Informatics Advanced Seminar on Information Visualization* 23.

Mayer, R. E. & Moreno, R. 2003. Nine Ways to Reduce Cognitive Load in Multimedia Learning. *Educational Psychologist* 38(1): 43-52.

Miller, G. A. 1956. The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information. *Psychological review* 63(2), 81 – 92.

Miller, P. H. 2002. Theories of Developmental Psychology. Macmillan New York.

Mitchell, M. & Newman, M. 2002. Complex Systems Theory and Evolution. *Encyclopedia of Evolution*, 1-5.

Moere, A. V. & Purchase, H. 2011. On the Role of Design in Information Visualization. *Information Visualization* 10(4): 356-371.

Morey J. & K. Sedig. 2004. Adjusting Degree of Visual Complexity: an Interactive Approach for Exploring Four-Dimensional Polytopes. *Vis. Comput. Int. J. Comput. Graph. 20, 1-21*.

Morey, J. & Sedig, K. 2004. Adjusting degree of visual complexity: An interactive approach for exploring four-dimensional polytopes. *The Visual Computer* 20(8-9): 565-585.

Murata, M., Nakajima, K., Tezel, A., Koskela, L., Tzortzopoulos, P., & Katayama, H. (2015). Investigation of visual management cases in construction by an analytical framework from manufacturing. *45th International Conference on Computers & Industrial 2015 (CIE45), 744-751.*

Ng C. L. I. 2011b. Complex Engineering Service Systems: A Grand Challenge. in *Complex Engineering Service Systems: Concepts and Research.* Ng C. L. I., Parry G., Wild, P. J., Mc Farlane, D. (eds.). 439-454, Springer.

Ng, C. L. I. 2011a. Innovating on Value SD Logic Approach. *Presentation of Wolfson College Cambridge.*

Noah, S. A., Yaakob, S. & Shahar, S. 2009. Application of Information Visualization Techniques in Representing Patients' Temporal Personal History Data. in *Visual Informatics: Bridging Research and Practice.* Badioze Zaman, H., Robinson, P., Petrou, M., Olivier, P., Schroder, H. & Shih, T. K. (Eds.). 168-179, Springer Berlin Heidelberg.

Nordin, P. & Banzhaf, W. 1995. Complexity Compression and Evolution. in International Conference of Genetic Algorithms of Sixth International Proceedings (ICGA). Eshelman, L. (ed.). 310-317, Morgan Kaufmann.

Norman, D. A. 1993. *Things that Make Us Smart: Defending Human Attributes in the Age of the Machine*. Basic Books.

Norman, D. A. 2005. Human-centered design considered harmful. *Interactions* 12(4): 14-19.

Norman, D. A. 2013. *The Design of Everyday Things: Revised and Expanded Edition*. Basic Books.

Northcote, M. T. 2012. Selecting Criteria to Evaluate Qualitative Research. Education Papers and Journal Articles. Paper 38. http://research.avondale.edu.au/edu_papers/38 [3 Februari 2015]

Nunamaker, J. F., Dennis, A. R., Valacich, J. S., Vogel, D. & George, J. F. 1991. Electronic Meeting Systems. *Communications of the ACM* 34(7): 40-61.

Oxford Dictionaries, 2016. http://www.oxforddictionaries.com.my [5 Januari 2016].

Paas, F., Renkl, A. & Sweller, J. 2003. Cognitive Load Theory and Instructional Design: Recent Developments. *Educational Psychologist* 38(1): 1-4.

Paas, F., Renkl, A. & Sweller, J. 2004. Cognitive Load Theory: Instructional Implications of the Interaction between Information Structures and Cognitive Architecture. *Instructional Science* 32(1/2): 1–8.

Parsons, P. & Sedig, K. 2014a. Adjustable Properties of Visual Representations: Improving the Quality of Human-Information Interaction. *Journal of the Association for Information Science and Technology* 65(3): 455-482.

Parsons, P. & Sedig, K. 2014b. Distribution of Information Processing While Performing Complex Cognitive Activities with Visualization Tools. in *Handbook of Human Centric Visualization.* Huang, W. (Ed.). 717–743, Springer New York Science Business Media.

Parsons, P., Sedig, K., Didandeh, A. & Khosravi, A. 2015. Interactivity in Visual Analytics: Use of Conceptual Frameworks to Support Human-Centered Design of a Decision-Support Tool. IEEE *48th Hawaii International Conference on System Sciences (HICSS)*, 1138-1147.

Patton, M. Q. 1990. *Qualitative Evaluation and Research Methods*. SAGE Publications.

Peffers, K., Tuunanen, T., Gengler, C. E., Rossi, M., Hui, W., Virtanen, V. & Bragge, J. 2006. The Design Science Research Process: a Model for Producing and Presenting Information Systems Research. *Proceedings of the first international conference on design science research in information systems and technology (DESRIST)*, 83-106.

Pfister, R. A. & Eppler, M. J. (2012). The benefits of sketching for knowledge management. *Journal of Knowledge Management* 16(2): 372-382.

Pouresia, A., Ahmadgourabi, M. & Efteghar, A. 2013. Balanced Scorecard: A new Tool for Performance Evaluation. *Interdiciplinary Journal of Contemporary research in Business* 5(1): 974-978.

Raje, R.R., Boyles, M. & Fang, S. 1998. CEV: Collaborative Environment for Visualization using Java RMI. in *Concurrency and Computation: Practice and Experience* 10(11–13): 1079–1085.

Redish, J. 2007**.** Expanding usability testing to evaluate complex systems. *Journal of Usability Studies* 2(3): 102-111.

Roschelle, J. 1992. Learning by collaborating: Convergent Conceptual Change. *The Journal of the Learning Sciences* 2(3): 235-276.

Sakamoto, S. G. and de Miranda, L. C. & Hornung, H. 2014. Home Control via Mobile Devices: State of the Art and HCI Challenges under the Perspective of Diversity. in *Universal Access in Human-Computer Interaction. Aging and Assistive Environments.* Stephanidis, C. & Antona, M. (eds.). 501-512, Springer International Publishing.

Scheffer, M. & Van Nes, E. H. 2006. Self-Organized Similarity, the Evolutionary Emergence of Groups of Similar Species. *Proceedings of the National Academy of Sciences* 103(16): 6230-6235.

Schmid, U., Ragni, M., Gonzalez, C. & Funke, J. 2011. The Challenge of Complexity for Cognitive Systems. *Cognitive Systems Research* 12(3-4): 211–218.

Sedig K. & Parsons, P. 2013. Interaction Design for Complex Cognitive Activities with Visual Representations: A Pattern-Based Approach. *AIS Transactions on Human-Computer Interaction* 5(2): 84–133.

Sedig, K., Parsons, P. & Babanski, A. 2012a. Towards a Characterization of Interactivity in Visual Analytics. *Journal of Multimedia Processing and Technologies* 3(1): 12–28.

Sedig, K., Parsons, P., Dittmer, M. & Haworth, R. 2013. Human-Centered Interactivity of Visualization Tools : Micro- and Macro-level Considerations. in *Handbook of Human Centric Visualization.* Huang, W. (Ed.). 717-743, Springer New York Business Media.

Sedig, K., Parsons, P., Dittmer, M. & Ola, O. 2012b. Beyond information access: Support for Complex Cognitive Activities in Public Health Informatics Tools. *Online Journal of Public Health Informatics* 4(3).

Senge, P. & Jaworski, J. 2011. *Synchronicity: The Inner Path of Leadership.* Berrett-Koehler Publishers.

Senge, P. 1990. *The fifth discipline: The art and science of the learning organization.* New York Currency Doubleday.

Shneiderman, B. 1996. The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations. *Visual Languages Proceedings IEEE Symposium,* 336-343.

Sitohang, B. 2013. Big Data is a Big Challenges. *The 4th International Conference on Electrical Engineering and Informatics*

Still, B. 2010. Mapping Usability: An Ecological Framework for Analyzing User Experience. in *Usability of Complex Information Systems: Evaluation of User Interaction*. Albers, M. & Still, B. (Eds.). 98-108. Boca Raton CRC Press.

Strauss, A. & Corbin, J. 1990. *Basics of Qualitative Research Volume 15*. Newbury Park Sage.

Suri, H. 2011. Purposeful Sampling in Qualitative Research Synthesis. *Qualitative Research Journal* 11(2): 63-75.

Sweller, J. & Van Merrienboer J. J. 2005. Cognitive Load Theory and Complex Learning: Recent Developments and Future Directions. *Educational Psychology Review* 17(2): 147–177.

System Thinking World. System Wiki http://systemswiki.org/index.php?title=Main_Page [12 September 2014].

Tergan, S. O. 2005. Digital Concept Maps for Managing Knowledge and Information. in *Knowledge visualization and information visualization: Searching for synergies.* Tergan, S.O. & Keller, T. (Eds.). 185-204, Springer Heidelberg.

Thomas, J. J. & Cook, K. A. 2005. Illuminating the Path: The Research and Development Agenda for Visual Analytics. *IEEE Computer Society.*

Tory, M. & Möller, T. 2004. Rethinking Visualization: A High-Level Taxonomy. *Information Visualization IEEE Symposium (INFOVIS 2004),* 151-158.

Vaishnavi, V. K. & Kuechler Sr, W. L. 2007. Design [science] research in IS—a work in progress. *Proceedings of the Second International Conference on Design Science Research in Information Systems and Technology (DESRIST 2007)*, 1-17.

Van Merrienboer, J. J. & Sweller, J. 2005. Cognitive Load Theory and Complex Learning: Recent Developments and Future Directions. *Educational Psychology Review* 17(2): 147-177.

Venable, J. 2006. The Role of Theory and Theorising in Design Science Research. *Proceedings of the 1st International Conference on Design Science in Information Systems and Technology (DESRIST 2006)*, 1-18.

Vitiello, P. F. & Kalawsky, R. S. 2012. Visual Analytics: A Sensemaking Framework For Systems Thinking in Systems Engineering. IEEE International Systems Conference (SysCon), 1-6.

Waldrop, M. 1992. *The Emerging Science at the Edge of Order and Chaos.* New York Simon and Schuster.

Waldrop, M. M. 1992. *Complexity: The Emerging Science at the Edge of Chaos*. Simons & Schuster Paperbacks.

Walls, J. G., Widmeyer, G. R. & El Sawy, O. A. 1992. Building an Information System Design Theory for Vigilant EIS. *Information Systems Research* 3(1): 36-59.

Woolfolk, A., Winne, P. H. & Perry, N. E. 2005. *Educational Psychology*. Pearson Canada.

Ya'acob, S., Ali, N. M., & Nayan, N. M. 2013. Understanding Big Picture and Its Challenges: Experts and Decision Makers Perspectives. *in Advances in Visual Informatics.* Badioze Zaman, H., Robinson, P., Olivier, P., Shih, T. K. & Velastin, S. (eds.). 311-322, Springer International Publishing.

Ya'acob, S., Ali, N. M., & Nayan, N. M. 2015. Systemic Visual Structures: Design Solution for Complexities of Big Data Interfaces. In *Advances in Visual Informatics.* Badioze Zaman, H., Robinson, P., Smeaton, A. F., Shih, T. K. & Velastin, S., Jaafar, A. & Ali, N. M. (eds.). 25-37. Springer International Publishing.

Yin R. K. 2011a. *Case Study Research Design 5th edition*. The Guilford Press New York.

Yin, R. K. 2011b. *Applications of Case Study Research*. Sage.

Yin, R. K., 2010. *Qualitative Research from Start to Finish*. The Guilford Press.

Zhang, J. & Norman, D.A. 1994. Representations in Distributed Cognitive Tasks. Cognitive Science: *A Multidisciplinary Journal* 18(1): 87–122.

Zhang, J., Zhong, D. & Zhang, J. 2010. Knowledge Visualization: An Effective Way of Improving Learning. Second International Workshop on Education Technology and Computer Science IEEE (ETCS) 1, 598-601.

Zhang, Y. & Wildemuth, B. M. 2009. Qualitative analysis of content. in *Applications of Social Research Methods to Questions in Information and Library Science*. Wildemuth, B. (Ed.). 308-319, Westport CT Libraries Unlimited.

Ziemkiewicz C. & Kosara, R. 2009. Embedding Information Visualization Within Visual Representation. in *Advances in Information and Intelligent Systems Studies in Computation Intelligence* 251. Ras, Z, W. and Ribarsky, W (eds.). 307-326, Springer Heidelberg.

Ziemkiewicz, C. & Kosara, R. 2010. Implied Dynamics in Information Visualization. *ACM Proceedings of the International Conference on Advanced Visual Interfaces*, 215-222.

Ziemkiewicz, C. & Kosara, R., 2008. The Shaping of Information by Visual Metaphors. *IEEE Transaction on Visualization and Computer Graphics* 14(6): 1269-1276.

Ziemkiewicz, C. 2010. Understanding the Structure of Information Visualization through Visual Metaphors. PhD Dissertation. University of North Carolina, Charlotte.

APPENDIX A - THE EXAMPLE OF THE ANALYSIS FOR SEMI STRUCTURED INTERVIEW

165	A – yes, kualiti mesyuarat tu kalau boleh nak dapatkan mesyurat untuk dapat keputusan,	T2, ST a – value of main driver
166	mandat daripada jabatan lain. Means that, Jabatan A sokong, jabatan B sokong bersyarat. So	
167	kalau benda tu nak buat melibatkan perubahan dasar besar, negara ke apa, baru you buat MJM,	
168	so at working level tu must be sorted out thoroughly. So takdelah mesyuarat tu datang	
169	melenggang, datang tak buat apa, datang makan karipap, balik	
170	S – satu lagi kan, in the meeting people bagi opinion, A bagi opinion, B bagi opinion.. so	
171	camana you atau you tengok orang lain handle opinion.	
172	A – satu lagi berkenaan pengendalian mesyuarat, bukan pengerusi aje tau yang mainkan	T1, ST a - Different roles
173	peranan penting, Orang yang duduk belah kanan pengerusi tu memainkan peranan penting.	NCA 1– Personalization - urusetia
174	Selalunya ketua urusetia la. Sebab pengerusi biasanya senior management. KSU ke, TKSU ke,	
175	timbalan menteri ke yang mempengerusikan. Selalunya sebelum mesyuarat la, dia bagi satu	
176	muka untuk dia cakap. So peranan urusetialah yang paling penting untuk check.. emm... hala	
177	tuju mesyuarat.	
178	S – I baru nak tanya soalan tentang urusetia mesyuarat. Tapi you dah bentang. Thank you very	
179	much.. hahaha..	
180	A – ketua urusetia memang main peranan penting. Ketua urusetia tak semestinya dia kena	NCA 1– Personalization - urusetia
181	bercakap. Ada setengah depend pada character bos, sesetengah bos tak suka anak buah lagi	
182	pandai daripada dia. Ada setengah tu, dia buat intro aje, then dia pass kat pengarah ni untuk	
183	lead the meetings, dia hadir di situ sebagai ceremonial. Ada setengah pengerusi yang involve.	
184	Ada setengah pengerusi yang abis aje intro terus pass. Kalau dia terus pass tu ok la, at least	T1, ST b - Different level of knowledge
	SME ada kat situ untuk guide mesyuarat. Again.. ketua urusetia dah automatik jadi pengerusi	- content

APPENDIX B - THE CONSENT FORM FOR FOCUS GROUP OBSERVATION

Institut Informatik Visual (IVI) | *Institute of Visual Informatics (IVI)*

BORANG MAKLUMAT DAN KEIZINAN PESERTA
(KAJIAN PENYELIDIKAN PHD)

1. Maklumat Kajian

1.1. Tajuk Kajian: **Rekabentuk Perwakilan Visual Bagi Menyokong Kolaborasi bagi Aktiviti Kognitif Yang Kompleks**

1.2. Nama Pelajar: Suraya binti Ya'acob

1.3. Nama Penyelia: Prof Madya Dr Nazlena binti Mohammad Ali
Prof Madya Dr Hai Ning Liang
Dr Norshita binti Mat Nayan

1.4. Pengenalan

Anda dipelawa untuk menyertai satu kajian kes berbentuk pemerhatian dalam kumpulan fokus yang melibatkan aktiviti kognitif yang kompleks. Dalam kes ini, satu mesyuarat atau perbincangan berkumpulan secara *face-to-face* akan dijalankan dalam membangunkan pelan strategi bagi pembangunan tanah. Ia adalah merupakan kes yang melibatkan aktiviti-aktiviti kognitif yang kompleks iaitu *brainstorming, sense making, forecast analysing* dan *decision making.*

Kajian kes ini adalah bermatlamat untuk mengenalpasti apakah produk (servis/solusi) yang paling sesuai untuk dijalankan pada tanah dengan keluasan ~2500 kaki persegi. Terdapat empat objektif / aktiviti yang akan dijalankan bagi memenuhi matlamat ini:

- Memahami situasi yang sedia ada
- Menyenarai dan brainstorming produk yang berpotensi untuk dijalankan.
- Memilih tiga jenis produk yang paling berpotensi untuk dikaji secara lebih lanjut.
- Merangka pelan pelaksanaan.

Penyertaan anda di dalam kajian ini dijangka mengambil masa diantara 45 – 75 minit bersama-sama dengan 4-5 orang peserta yang lain.

Peranti visual akan dipaparkan pada kumpulan peserta sebagai rujukan utama sepanjang aktiviti perbincangan dijalankan. Interaksi diantara peserta, respon kepada soalan dan memberi cadangan dan idea adalah amat digalakkan sepanjang perbincangan. Selain daripada itu, peserta juga adalah amat digalakkan untuk mencatat, melorek, menyambung dan melukis apa sahaja yang sesuai untuk menggambarkan idea yang ada dalam fikiran.

1.5. Tujuan Kajian

Kajian ini bertujuan untuk menilai impak penggunaan rekabentuk struktur visual dalam membantu dan memandu semasa proses menjalankan aktiviti kognitif yang kompleks. Impak akan dinilai daripada proses dan hasil semasa perbincangan bagi melihat keupayaan kumpulan peserta dalam:

i. Mengenalpasti 7 elemen dalam membentuk gambaran menyeluruh.
ii. Menangani elemen-elemen *emergence* yang muncul sepanjang perbincangan.

2. Kelayakan Penyertaan

- **Bagi pemilihan untuk kumpulan dalam kategori *novice*, semua peserta yang terlibat mestilah baru atau tiada pengalaman dalam domain pengetahuan yang hendak dibincangkan (kurang daripada 3 tahun dalam domain perbincangan).**
- **Bagi kesesuaian pembentukan kumpulan kolaborasi, penyertaan peserta individu mestilah memiliki motivasi dan minat terhadap dengan tajuk yang hendak dibincangkan.**
- **Pemilihan pada peringkat individu adalah bersifat rawak bagi memberi keutamaan kepada kesesuaian peserta secara kolaborasi dan motivasi terhadap tajuk domain pengetahuan yang hendak dibincangkan.**

3. Prosedur-prosedur Kajian

3.1. Sebelum Kajian

a. Mengesahkan penyertaan peserta
b. Pembahagian kumpulan dimaklumkan kepada peserta
c. Sebelum menjalani pemerhatian secara kumpulan fokus, anda dikehendaki untuk menduduki ujian Human Matriks secara atas talian (http://www.quistic.com/personality-test). Menerusi ujian ini, jenis proses kognitif setiap peserta akan dapat ditentukan melalui gabungan empat elemen iaitu *sensation, intuition, thinking and feeling.* Ini secara tidak langsung akan memberi peluang bagi setiap peserta mengenali potensi diri masing-masing dan berupaya untuk memahami sekiranya terjadi perbezaan pendapat dan idea dengan ahli kumpulan yang lain.
d. Persediaan bagi perekodan video, instrument kertas sketching dan marker, borang jawapan subjektif pada lokasi pemerhatian secara kumpulan fokus.

3.2. Sejurus Sebelum pemerhatian secara pemerhatian secara kumpulan fokus dijalankan

a. 4-6 orang peserta akan membentuk satu kumpulan berdasarkan kepada domain pengetahuan.
b. Setiap kumpulan akan ditempatkan pada lokasi pemerhatian secara kumpulan fokus yang sama dengan settings perbincangan atau mesyuarat.
c. Setiap kumpulan akan dijelaskan tentang prosedur sebelum pemerhatian secara kumpulan fokus mula dijalankan.
d. Kumpulan akan dimaklumkan tentang kepentingan untuk merujuk kepada peranti visual sepanjang aktiviti dijalankan.
e. Selain itu, peserta juga dimaklumkan terhadap kepentingan bersifat responsif dalam perbincangan (samada secara verbal atau visual *sketching*).
f. Peserta akan dimaklumkan apabila pemerhatian secara kumpulan fokus bermula dan perekodan video dan audio akan dimulakan.
g. Memberi pengenalan terhadap peranti dan rekabentuk visual yang akan digunakan oleh peserta sejurus sebelum aktiviti dijalankan.

3.3. Semasa pemerhatian secara kumpulan fokus dijalankan

a. Setiap ahli kumpulan dikehendaki untuk **menjalankan pemerhatian secara kumpulan fokus** berdasarkan kepada matlamat dan objektif yang telah dikenalpasti.
b. Pengkaji akan bertindak sebagai fasilitator sepanjang tugasan dijalankan. Peserta boleh mengajukan persoalan pada bila-bila masa sepanjang perbincangan.
c. Penerangan akan dibuat terhadap kaedah penggunaan struktur visual yang akan digunakan sejurus sebelum setiap objektif dijalankan.

3.4. Selepas pemerhatian secara kumpulan fokus dijalankan

a. Apabila telah selesai menjalankan tugas setiap objektif dan penyimpulan terhadap matlamat yang hendak dicapai, maka satu perbincangan untuk menjelaskan sebarang kekeliruan semasa aktiviti perancangan strategi akan dijalankan.
b. Selepas itu, perekodan video akan dihentikan

4. Penyertaan Dalam Kajian

Penyertaan anda dalam kajian ini adalah secara sukarela. Anda boleh menolak penyertaan dalam kajian ini atau anda boleh menamatkan penyertaan anda dalam kajian ini pada bila-bila masa, tanpa sebarang hukuman atau kehilangan sebarang manfaat yang sepatutnya diperolehi oleh anda.

5. Saguhati Penyertaan dan Rawatan untuk Kecederaan

Setiap kumpulan akan diberikan bayaran saguhati sebanyak RM500.00 memandangkan tahap kesukaran pemerhatian secara kumpulan fokus yang dijalankan.

6. Soalan dan pertanyaan lanjut

Sekiranya anda mempunyai sebarang persoalan dan memerlukan penerangan lanjut mengenai kajian ini atau hak-hak anda, sila hubungi;

Prof Datuk Dr Halimah Badioze Zaman
Pengarah Institut Visual Informatik UKM
Blok D, Bangunan MTDC,
Universiti Kebangsaan Malaysia,
43600, Bangi, Selangor
No. Tel: 03-89216073

7. Kerahsiaan

Maklumat dan hasil perbincangan anda akan dirahsiakan dan tidak akan dedahkan secara umum melainkan jika ia dikehendaki oleh undang-undang. Rekod maklumat anda dan kumpulan anda yang asal mungkin akan dilihat oleh pihak pensyarah, penaja dan/atau wakil-wakilnya, Lembaga Etika kajian ini dan pihak berkuasa regulatori untuk tujuan mengesahkan prosedur dan/atau data kajian. Maklumat anda mungkin akan disimpan dalam komputer dan diproses dengannya.

Dengan menandatangani borang persetujuan ini, anda membenarkan penelitian rekod, penyimpanan maklumat dan pemindahan data seperti yang dihuraikan di atas.

Borang Keizinan Peserta
(Halaman Tandatangan)

Tajuk Kajian: **Rekabentuk Perwakilan Visual Bagi Menyokong Kolaborasi bagi Aktiviti Kognitif Yang Kompleks**

Nama Penyelidik: Suraya binti Ya'acob

Untuk menyertai kajian ini, anda atau wakil sah anda mesti menandatangani mukasurat ini. Dengan menandatangani mukasurat ini, saya mengesahkan yang berikut:

- **Saya telah membaca semua maklumat dalam Borang Maklumat dan Keizinan Peserta ini dan saya telah pun diberi masa yang mencukupi untuk mempertimbangkan maklumat tersebut.**
- **Saya, secara sukarela, bersetuju menyertai kajian penyelidikan ini dan mematuhi segala prosedur kajian serta memberi maklumat yang diperlukan apabila diminta.**
- **Saya boleh menamatkan penyertaan saya dalam kajian ini pada bila-bila masa.**
- **Saya telah pun menerima satu salinan Borang Maklumat dan Keizinan Peserta untuk simpanan peribadi saya.**

_____ _____

Nama Peserta **(Boleh ditulis tangan)** Nama Singkatan dalam kajian kes

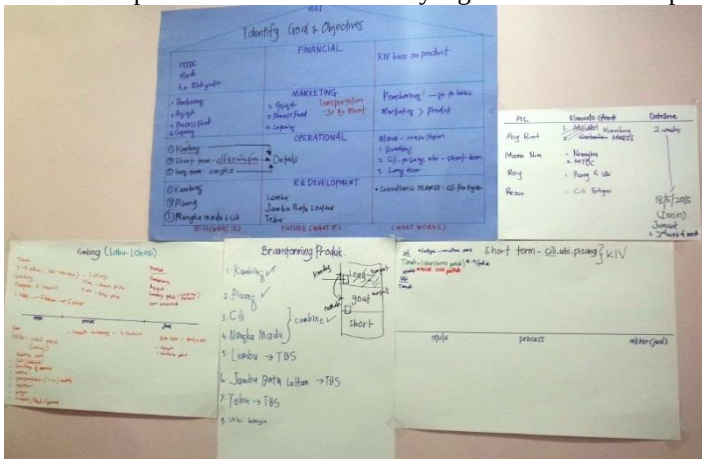
_____ _____

Tandatangan Peserta **Tarikh** (dd/mm/yy)

APPENDIX C - THE EXAMPLE OF THE ANALYSIS FOR FOCUS GROUP OBSERVATION

56	R – dua minggu la kita prepare. Sampai next meeting, kita dah tau … berapa ringgit kena keluar. Kita agak agakla, dalam satu ekar… boleh ke? Semua
57	satu ekar la.. agak agak modal satu ekar la untuk semua produk. Kos jualan berapa? Kos modal dia berapa nak start? Kos starting – modal, benih,
58	fertelizer, maintenance, racun, kena details out. Next meeting kita kena detail outs.
59	M – next meeting kena ada figure la.
60	R – ha.. lepas tu, baru kita boleh tarik masuk dalam financial. Marketing semua tu kita akan pecahkan. Lepastu baru detail out berapa semuanya
61	H – ada sesiapa tak lagi ada pertanyaan apa-apa sebelum kita boleh tutup
62	B - Jadi sebenarnya tujuan kita ni nak buat feasibility study kan? Entah berbaloi entah tidak nak develop tanah tu. Kalau daripada sini kita dah
63	nampak tak berbaloi untuk bangunkan, baik tinggalkan terus daripada kita terus jalankan tapi rugi at the end.
64	R – basically yes. Sebab tu kita kena pastikan produk yang kita pilih tu berbaloi.
65	M – kita kena kasik berbaloi la.. eh, pisang tu pisang tanduk ke pisang apa apa?
66	B- pisang apa-apa
67	H – so ok la kan.. ini semua eh, so sekarang kita dah tau apa benda yang kita nak buat. Lagi 26 mei kita boleh meeting la kot. Mungkin meeting kat
68	sini jugak la kot.
69	B – 26 tu kita dah target nak pergi MARDI untuk kursus pengurusan tanah terbiar…
70	R – boleh tak kita target sekali terus aje, maksudnya that night aje kita meeting.
71	M – lepastu?
72	R – maknanya komitmen kita itu aje…
73	M – tiap dua minggu meeting?
74	R – boleh ke kita bagi komitmen setiap dua minggu sekali meeting? Lock on that night
75	H – macamana boleh?
76	B – planningnya boleh la

Figure A: The example of Transcription for the Focus Group Observation

Sub-tema	Contoh
1. Jelas dengan isu utama (Justifikasi 1)	***Sumber 1: Audio (transkrib)*** **P 1: transkripsi kajian kes 1 - novice agrikultur.docx - 1:1 [Jadi kita mula daripada RnD du..] (62-64) (Super)** Codes: [2P Mendapatkan penjelasan tentang isu utama] Line 62-64, Minit 124:03 – 127:33 B - Jadi sebenarnya tujuan kita ni nak buat feasibility study kan? Entah berbaloi entah tidak nak develop tanah tu. Kalau daripada sini kita dah nampak tak berbaloi untuk bangunkan, baik tinggalkan terus daripada kita terus jalankan tapi rugi at the end. ***Sumber 2: Pemerhatian (nota lapangan, video)*** Setelah melihat dan memahami keseluruhan hasil perbincangan pada peranti visual setelah selesai perbincangan. ***Sumber 3: Kandungan Peranti Visual*** Gambar/snapshot keseluruhan content yang telah diisi setelah perbincangan.  **<u>Interpretasi Analisis:</u>** Diakhir perbincangan (peserta mengutarakan pendapat ini setelah semua aktiviti dijalankan – minit 124:03 – 127:33). Setelah melalui keseluruhan perbincangan dan meneliti keseluruhan isi kandungan hasil perbincangan dalam peranti visual, peserta memahami nilai yang boleh diperolehi hasil daripada matlamat atau tujuan sebenar perbincangan ini diadakan.

(Justifikasi 2)

Sumber 1 – Audio(transkrib)

P 1: transkripsi kajian kes 1 - novice agrikultur.docx - 1:1 [Jadi kita mula daripada RnD du..] (30:35) (Super)

Codes: [2P Mendapatkan penjelasan tentang isu utama] Line 30-35, minit 00:00 – 03:28

R -Jadi kita mula daripada RnD dulu, nak tengok apa produk yang kita nak tanam? Sekarang ni kita tengok daripada
What is [menunjuk kepada bahagian pertama peranti visual] daripada apa yang ada
What if [menunjuk kepada bahagian kedua peranti visual] apa yang sebenarnya kita nak buat dan What workable [menunjuk kepada bahagian ketiga peranti visual] iaitu apa sebenarnya yang praktikal untuk kita buat antara dua ni lah setelah nampak antara what is dan what if.

Sumber 2 – Pemerhatian

Penerangan diatas dibuat dengan merujuk kepada pelan rumah Kapplan. pada awal perbincangan (minit 00:00 03:28). Semasa penyatakan diatas dibuat, dengan menyemak pada struktur yang ada pada rumah Kapplan, responden M dan B mengangguk-ngangguk. Jelas pada riak wajah peserta yang mereka baru mengetahui apakah langkah-langkah yang perlu dilalui untuk membangunkan pelan strategi perniagaan pada tanah yang ada.

Sumber 3 – Kandungan dan Struktur Peranti Visual yang berkaitan.

Model Rajah Kaplan sebagai struktur utama perbincangan yang dibahagikan kepada empat lajur bagi mewakili 4 fasa yang perlu dilalui dalam proses membangunkan produk perniagaan. (masukkan gambar) - hanya struktur asal sahaja, belum dimasukkan content perbincangan.

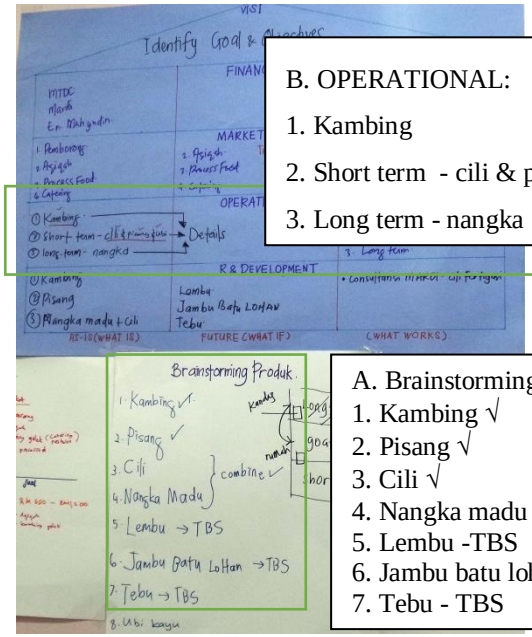
Interpretasi Analisis:

Peserta jelas terhadap apakah fasa-fasa penting yang perlu difahami dalam proses membangunkan pelan strategi perniagaan ini. Walaupun merujuk kepada Model Kapplan yang masih kosong, hanya dengan berpandukan struktur utama pelan strategi, peserta berupaya untuk memahami kepentingan untuk memahami fasa what is, what if, what works dalam membangunkan produk perniagaan. Ini memberikan gambaran bahawa melalui struktur yang jelas, peserta berupaya untuk melihat struktur keseluruhan dan seterusnya memahami matlamat utama yang hendak dicapai dalam perbincangan yang hendak dijalankan.

2. Mampu untuk melihat dan menggariskan hubungkait diantara elemen utama dalam membentuk perspektif. (Justifikasi 1)	**Selected Quotations (3).** **P 1: transkripsi kajian kes 1 - novice agrikultur.docx - 1:5 [M – ha... ok la, jadi kita ada..] (240:241) (Super)** Codes: [2P berupaya untuk mengenalpasti elemen-elemen utama] No memos M – jadi kita ada tujuh: kambing, pisang, cili, nangka madu, lembu, jambu dengan tebu.. enough eh? H – hmm... ok enough. **P 1: transkripsi kajian kes 1 - novice agrikultur.docx - 1:22 [H – so sekarang ni pun, banyak..] (686:690) (Super)** Codes: [2P berupaya untuk mengenalpasti elemen-elemen utama] No memos H – so sekarang ni pun, banyak R – better.. kambing, pisang, cili, ubi kayu. What do you think? B – ini antara yang confirm la H – ok... kambing, pisang, cili, ubi kayu. [sambil menulis keputusan di papan utama] **P 1: transkripsi kajian kes 1 - novice agrikultur.docx - 1:25 [H – so sekarang kita dah fokus..] (715:718) (Super)** Codes: [2P berupaya untuk mengenalpasti elemen-elemen utama] No memos H – so sekarang kita dah fokus kan.. R – sebab yang tu... H – short term dulu la kan? R – short term kita boleh pergi cili dan ubi kayu **Instrumen 2 – Pemerhatian** Dengan merujuk kepada struktur segmen bagi pemilihan produk, pasukan kolaborasi akan membincang dan mencatatkan setiap satu produk yang dibincangkan dalam bentuk senarai dalam kotak perbincangan produk. Mereka berhenti apabila telah menyenaraikan tujuh jenis produk dalam kotak tersebut. Kemudian daripada tujuh senarai yang ada, mereka menyenarai

pendek dengan memilih hanya tiga produk sahaja untuk dilaksanakan. Tiga produk tersebut adalah setiap satunya mewakili produk perternakan, jangkamasa pendek dan jangkamasa panjang.
Tiga produk yang dipilih ini kemudiannya direkodkan ke dalam ruangan produk dalam struktur utama rumah Kapplan.

Instrumen 3 – Kandungan dan Struktur Peranti Visual yang berkaitan.
Rajah dibawah adalah struktur dalam peranti visual yang terlibat dalam proses senarai pendek produk. Pada mulanya peserta menyenaraikan tujuh jenis produk yang berpotensi (ditunjukkan dalam struktur A). Kemudian daripada senarai tersebut, mereka membuat tiga pilihan dan memasukkan pula pilihan tersebut ke dalam senarai perspektif operasi (ditunjukkan dalam struktur B).



B. OPERATIONAL:

1. Kambing
2. Short term - cili & pisang & ubi
3. Long term - nangka

A. Brainstorming Produk
1. Kambing √
2. Pisang √
3. Cili √
4. Nangka madu √
5. Lembu -TBS
6. Jambu batu lohan - TBS
7. Tebu - TBS

Intepretasi analisis
Kumpulan peserta sebenarnya adalah dalam proses mensintesis daripada tujuh produk yang telah disenaraikan kepada tiga produk sahaja mengikut pengkelasan produk ternak, jangka masa pendek (short term) dan jangka masa panjang (long term)

Proses pemilihan daripada tujuh produk kepada tiga produk mengikut pengkelasan yang diperlukan adalah merupakan proses *convergence* yang diperlukan bagi membentuk perspektif produk yang lebih abstrak seperti yang diperlukan dalam kerangka

utama pelan strategi. Untuk mendapatkan senarai pendek ini, peserta berupaya menghubungkait dan mengkelaskan tiga elemen utama produk mengikut jenis (ternakan, *short term* dan *long term*) daripada keseluruhan tujuh jenis produk yang ada. Kemudian, dengan memilih produk yang bersesuaian mengikut tiga jenis tersebut sebenarnya adalah membentuk perspektif produk yang berpotensi untuk dioperasikan.

Menerusi penetapan tiga perspektif dalam struktur Model Kapplan, peserta kolaborasi memahami keperluan untuk menyimpulkan perincian produk kepada perspektif produk yang lebih abstrak untuk dimuatkan dalam Model Kapplan, secara tidak sedar memerlukan mereka membuat perbandingan diantara senarai produk yang ada dan menyimpulkan pilihan bagi membentuk perspektif yang lebih abstrak bagi memilih produk yang paling sesuai untuk dilaksanakan.

Produk	**Elemen utama**	**Perspektif**
Kambing, lembu	Ternakan	Perspektif operasi
Ubi, cili, pisang, Tebu	Short term	
Nangka, Jambu	Long term	

3.Mendapatkan maklumat terperinci mengikut paras yang diperlukan (Justifikasi 1)

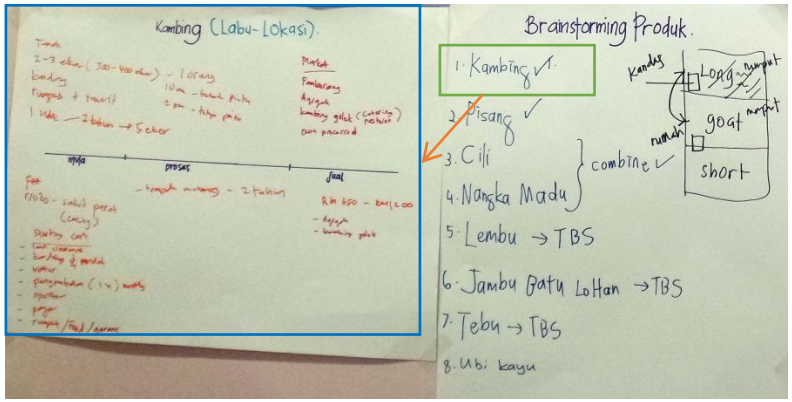
Selected Quotations (7).

HU: coding validasi kumpulan 1
File: [C:\coding validasi kumpulan 1.hpr7]
Edited by: Super
Date/Time: 2015-05-25 15:56:36

Instrumen 1: Transkribsi
P 1: transkripsi kajian kes 1 - novice agrikultur.docx - 1:7 [H - So sekarang kita nak pergi..] (323:323) (Super)
Codes: [2P mendapatkan maklumat terperinci mengikut paras yang diperlukan]
No memos
H - So sekarang kita nak pergi mana untuk detail produk? Kambing la kan? Brainstorming kambing.

Instrumen 2: Pemerhatian
Dengan menyemak semua produk yang disenaraikan dalam struktur visual, maka barulah produk yang berpotensi akan dipilih untuk perbincangan yang lebih lanjut. Untuk menfasilitasi perbincangan yang lebih terperinci maka struktur visual Journey Mapping telah disediakan untuk memperihalkan secara lebih mendalam tentang produk kambing.

Instrumen 3 – Kandungan dan Struktur Peranti Visual yang berkaitan.



Intepretasi analisis

Pergerakan perbincangan daripada struktur senarai produk (yang menunjukkan senarai produk secara abstrak) kepada struktur visual journey mapping (untuk perbincangan yang lebih terperinci tentang sesuatu produk yang terpilih) secara tidak langsung memandu pasukan kolaborasi untuk mendapatkan maklumat terperinci mengikut paras yang diperlukan.

(Justifikasi 2)

Instrumen 1: Transkribsi

A - Settings kambing

P 1: transkripsi kajian kes 1 - novice agrikultur.docx - 1:8 [B – keperluan makanan dia rump..] (384:384) (Super)
Codes: [3P mendapatkan maklumat terperinci mengikut paras yang diperlukan]
No memos

B – Kambing kita dah ada kes study la (merujuk kepada Alwigoatfarm). Dalam range 2-3 ekar tanah
[sambil menulis ---------- di journey mapping]
Dia perlukan kandang. Ikut kita nak scale besar mana. 2-3 ekar ni boleh muatkan 300 hingga 400 ekor kambing.
M – Kandang tu besar sekali sampai muatkan 3 hingga 4 ratus ekor kambing tu ke?
B – haah. Tapi dalam kandang tu dia tak perlukan ruang yang luas. Yang penting kandang dan kawasan dia meragut rumput. Lagi cantik kalau kawasan rumput ni dia campur dengan kawasan yang teduh. Contohnya macam kelapa sawit la, kelapa sawit ni selalunya bawah dia bersih jadi rumput boleh hidup jugak, jadi dia(merujuk kepada kambing) makan rumput tu aje. So untuk tanah kita belukar... agak sukar untuk.. kita kena tanam rumput dulu

H – kita tanam rumput sahaja atau tanam?
B – rumput untuk makanan dia..
H – ooo.... tak boleh ke kalau kita tanam pokok kan... pokok yang medium kekal – nangka madu dan jambu and then kita tanam rumput boleh?
B – nak sampai besar tu, its quite.. kalau kita starting daripada ni... Lagi satu, satu induk kita boleh untuk dua tahun purata 5 ekor dia punya anak.
M – maknanya sekor tambah lima ekor
B – sekor lahir lima ekor.
R – dua ekor setahun la
B – penyakit dia yang dia selalu kena is sakit perut. Kecacingan la
H – [ketawa]
B – dan lagi satu kalau dia ada contamination daripada penyakit luar. Kalau ada kambing luar campur dengan dia. Boleh kena penyakit jugak *[mencatat _____ di board]*
B – tapi semua ni boleh pakai ubat aje la
M – ooo... tak mati la
R – takde ubat mati la
H – ubat kita dapat free ke kita kena beli?
B – kena beli
M – mahal tak ubat ni?
B – harga ubat kalau ikutkan tak mahal la, tak significant untuk cost operational. Dan kos operatonal untuk 3 ekar tu, dia perlu sorang aje
B – kerja dia katalah pukul 10 pagi, dia pergi kandang kambing bukak pintu, biar kambing jalan, biar kambing keluar. Pastu pukul 2.... kambing masuk balik *[sambil mencatat _____ di board]*
kalau dia tak halau pun, kambing tu balik sendiri la
M – balik rumah sendiri?
B – aah, balik rumah sendiri. keperluan makanan dia rumput aje, Cuma ada la kalau kambing yang tak sihat, dia perlu la dia bagi makan tu, yang tu dia bagi kat kandang je la. Aaa....then jaga air. Air salah satu isu penting, sebab supply air aaa... kalau dalam banyak kes yang diorang kena is kencing tikus. So kambing punya penyakit daripada kencing tikus, bila bekalan air tu kena kencing tikus, kambing pun sakit.
M – aa... dia punya tempoh?
B – tempoh matang?
M – aa... tempoh boleh makan
B – kalau ikut akikah...tempoh umur kambing, du..... berapa tahun?
[cuba dapatkan confirmation orang lain]

H – akikah dua tahun...

Instrumen 2: Pemerhatian

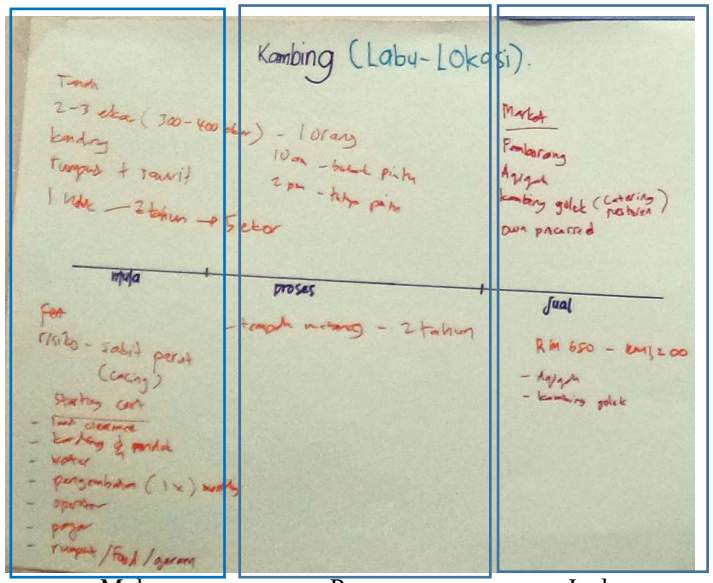
Bagi membincangkan maklumat secara terperinci tentang produk kambing, Perjalanan proses perbincangan membangunkan produk merujuk kepada proses penternakan kambing. Dengan merujuk kepada struktur journey mapping bagi produk kambing yang telah dibahagikan kepada tiga elemen utama dalam menjalani proses untuk membangunkan sesuatu produk iaitu:

i. mula (Settings) - keperluan untuk memulakan sesuatu produk,
ii. Proses – keperluan aktiviti-aktiviti yang perlu dijalankan untuk melaksanakan sesuatu produk.
iii. Jual (Tamat) – keperluan untuk memasar dan menjual produk tersebut.

Justeru itu, sepanjang membincangkan maklumat terperinci tentang kambing, perbincangan yang diadakan adalah berstruktur dan tersusun mengikut fasa settings, proses dan tamat seperti yang digariskan dalam journey mapping.

Instrumen 3: kandungan

Hasil perbincangan dicatat dalam elemen settings, proses dan tamat bagi journey mappings kambing.



Mula Proses Jual

Intepretasi Analisis

Berdasarkan kepada struktur quotation perbincangan menunjukkan penceritaan dan perbincangan yang dibuat adalah tersusun daripada fasa mula, proses sehingga kepada fasa tamat dalam membincangkan produk kambing seperti mana yang distrukturkan dalam struktur visual journey mappings. Ini menunjukkan bahawa struktur journey mapping yang telah distrukturkan kepada elemen mula, proses dan jual berupaya untuk memandu para peserta kolaborasi membincangkan perincian secara berstruktur mengikut fasa yang diperlukan.

(Justifikasi 3)

Instrumen 1: Transkrib

P 1: transkripsi kajian kes 1 - novice agrikultur.docx - 1:13 [B – tempoh matang dia dua tahu..] (420:420) (Super)

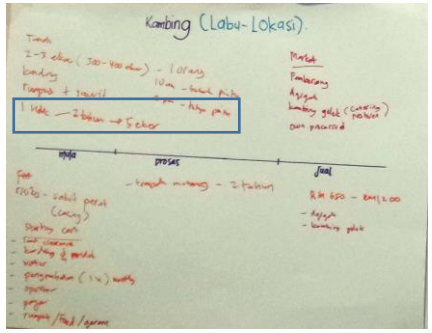
Codes: [2P mendapatkan maklumat terperinci mengikut paras yang diperlukan]

B – tempoh matang dia dua tahun. Kalau kita ada 10 induk, dalam 2 tahun dia jadi 50. Dalam masa 4 tahun... emm nanti la kita kira balik.

Instrumen 2: Pemerhatian

Peserta bertindak mencatat hasil perbincangan dalam ruangan journey mapping produk kambing. Semasa membincangkan secara terperinci tentang produk kambing, peserta mencari-cari ruang untuk membuat catatan bagi kiraan tersebut dan mendapati bahawa perkara utama iaitu 1 induk boleh berkembang kepada 5 ekor dalam masa 2 tahun telah sedia dicatat dalam ruangan mula. Maka semasa membuat kiraan dan membincangkan hal tersebut, perincian terhadap perkembangan kepada 50 ekor dalam masa 2 tahun dan 4 tahun tidak dimasukkan ke dalam journey mapping bagi produk kambing.

Instrumen 3: Kandungan dan Struktur Peranti Visual yang berkaitan



Kandungan catatan dalam kotak ini:

1 Induk – 2 tahun – 5 ekor

Interpretasi analisis

Semasa membuat rujukan pada journey mapping, peserta telah menyedari bahawa elemen terperinci tentang baka kambing iaitu 1 induk -2 tahun –> 5 ekor telah dicatat dalam ruangan yang mula. Jumlah perkembangan kambing dengan pertambahan bilangan induk (kepada 10 ekor induk) atau pertambahan bilangan tahun (kepada 4 tahun) mestilah merujuk kepada formula di atas. Justeru itu, apabila mendapati formula di atas telah dicatatkan, maka sebarang unjuran perkembangan kambing berdasarkan formula tersebut adalah merupakan maklumat yang terperinci dengan berpandukan formula tersebut dan tidak perlu untuk dicatatkan atau dibincangkan secara lebih mendalam Justeru itu, dengan berpandukan kepada kandungan maklumat yang dicatat dalam struktur visual journey mappings dilihat berupaya untuk menyedarkan perbincangan supaya tidak berlanjutan terus menerus membincangkan tentang sesuatu maklumat dengan paras yang jauh lebih mendalam dan berupaya untuk berpatah balik kepada perkara yang lebih pokok (abstrak) untuk dibincangkan.

(Justifikasi 4)

P 1: transkripsi kajian kes 1 - novice agrikultur.docx - 1:13 [B – tempoh matang dia dua tahu..] (420:420) (Super)
Codes: [2P mendapatkan maklumat terperinci mengikut paras yang diperlukan]
No memos
*B – tempoh matang dia dua tahun. Kalau kita ada 10 induk, dalam 2 tahun dia jadi 50. Dalam masa 4 tahun**... emm nanti la kita kira balik.***
Good point – berupaya untuk berpatah balik bila bincang terlalu details

Selected Quotation

HU: coding validasi kumpulan 1
File: [C:\coding validasi kumpulan 1.hpr7]
Edited by: Super
Date/Time: 2015-05-25 16:11:57

P 1: transkripsi kajian kes 1 - novice agrikultur.docx - 1:21 [menyedari perbincangan terlalu..] (669:670) (Super)
Codes: [menyedari perbincangan terlalu mendalam dan kembali kepada paras yang lebih abstrak]
No memos
H - Ha ok la kan.. Sekarang kita cerita produk lain pulak. Pisang?
menyedari perbincangan terlalu mendalam dan terperinci tentang kambing dan bersifat uncertainties pada mereka, jadi berbalik kepada pokok perbincangan yang lebih abstrak.

Figure B: The example of Deductive Qualitative Analysis for the Group Study Observation

APPENDIX D – THE INVITATION LETTER FOR THE EXPERT REVIEW

UNIVERSITI KEBANGSAAN MALAYSIA
The National University of Malaysia

Institut Informatik Visual (IVI) | *Institute of Visual Informatics (IVI)*

30 Mac 2016

YBrs. Dr Mohammad Nazir Ahmad
Jabatan Sains Maklumat, Fakulti Pengkomputeran
Universiti Teknologi Maklumat
81310, Johor Bahru, Johor Darul Ta'zim.

Melalui
Prof Madya Dr Nazlena Mohamad Ali (Penyelia Utama)
Institut Visual Informatik, UKM,
43600, Bangi, Selangor.

YBrs Dr,

Permohonan Pandangan Pakar

2. Adalah dimaklumkan bahawa saya, Suraya binti Ya'acob (P64774) adalah merupakan pelajar PhD di Institut Visual Informatik (IVI). Maklumat lanjut tentang pengajian saya adalah seperti berikut;

Tajuk Pengajian	: Reka bentuk Perwakilan Visual untuk Menyokong Kolaborasi bagi Aktiviti Kognitif yang Kompleks.
Penyelia utama	: Prof Madya Dr Nazlena Mohamad Ali.
Penyelia bersama	: Prof Madya Dr Hai Ning Liang

3. Saya berhasrat untuk mendapatkan pandangan pakar daripada YBrs. Dr dalam bidang Design Science Research Methodology (DSRM) yang merupakan metodologi yang diaplikasikan dalam bidang penyelidikan yang sedang saya jalankan. Bersama-sama ini disertakan juga ringkasan tentang kajian tersebut. Sekiranya memerlukan sebarang maklum balas lanjut, boleh hubungi saya melalui nombor telefon 012-9330838 atau email kepada *surayayaacob@gmail.com.*

4. Pertimbangan dan kerjasama daripada YBrs Dr. adalah amat dihargai.

Sekian, terima kasih.

Yang Benar,

……..
(Suraya binti Ya'acob)

APPENDIX E - THE OVERALL FINDINGS FROM SEMI STRUCTURED INTERVEW

Theme	Subtheme	Sub-subtheme	Corresponding key ideas
Theme 1: Context of use and group fit design	(a). Different roles of the users	i) Guidance is depending on the roles of the chairperson and secretariat.	• The Collaborative-CCA process and outcomes are depending on the roles of the leader and secretariat. • Other users are playing a passive mode during the collaboration (especially on the directive process).
		ii) The valuable and quality outcomes is depending on the roles, knowledge and skills of the users	• Experience help a lot during the collaborative process because cognitive backgrounds through experience helps the users about the how knowledge and easily • The valuable and quality of the decision (outcomes) rely more on the context and the background of the users – because they know the how knowledge (context) and content knowledge
		iii) The significant of secretariat roles especially in the multi level of collaborative CCA	• Secretariat play an important roles to manage the Collaborative-CCA • The Collaborative-CCA process takes place from lower to higher level of the Collaborative-CCA
		iv) The differences between experts and decision makers point of view	• Decision Makers mostly involves the whole/various field of expertise while SME/Experts mostly focus on the experts
	(b) Different level of knowledge	i) Know the content	• Experiences help to develop the expertise in certain subject matter. • Know the content –let the users being knowledgeable in that area. • The knowledegeable collaborator is valuable in the process.
		ii) Know the context	• Experiences help to know what step to be taken in order to handle the Collaborative-CCA process like decision making or problem solving. • Know where to refer, who are the people in charge and which policy to be considered

		iii).Group members who don't know	• The collaborator in the group keeps quiet because they don't know what to ask and how to get involved (being passive-'ahli tidur') • Lead for trial and error solution • The collaborator in the group keeps quiet even when they know because the superior doesn't know - they keep silent to maintain the boss reputation (status quo)
	(c) Different skill of communication, type of learning and background		
	(d) Pattern of incoming issues		
Theme 2: The lack of understanding the importance of convergence	(a)The difficulties to clarify the main driver	(i). The main driver is instructive (too tight) or abstractive (too loose).	• Highlight the importance of main driver to guide the collaboration. • The needs for determined and instructive pattern of main drivers (too tight) let the process of CCA • Objective as main driver is too general, the collaborators don't have the guidelines to centralize and externalize their shared mental model (too loose).
		(ii). Difficulties to appreciate the value of main drivers	• Value for CCA process is more like to finish the task instead of solving the CCA • Care about the value and benefit of outcome due to their own self interest.
		(iii). Difficulties to sustain the main driver direction	• Deviation during more increasing complexities. • Blurriness when others talking about their field of expertise (too details, too deep). • Lost when the chairperson unable to control the discussion • Lost when the chairperson incapable to summarize the content of discussion.
	(b) The difficulties to see and draw the interconnectedness of information.	i) Various and multi sources of information.	• Information come from various and multisources. • Different experts, units, departments hold different ownership of information. • More concerned about their self interest (e.g. their individual, representing unit, department or agencies) compared to the shared vision, • Being open for convergence might jeopardize their self-interest. Since they don't see, they don't care for others' interests.
		ii) The collaborators are in the determination approach	• The users aim for job completion instead of value in handling the CCA. • Open for convergence might delay the task and job execution.

		iii) No guidelines during higher level thinking (convergence)	• Need an explicit reminder and reference throughout the process (e.g, memorandum, tentative and agenda) • No supporting tools while doing the higher level thinking • The higher level thinking happens in the user's head / in silo. • Less of constructive arguments and reasoning – why and how for each of the consideration
		iv) Mental Overload during convergence	• Too much information and it is difficult to be written (they don't know what to write) • Unsure which information to drop. • Too complex, so the collaborators tend to focus on what they are able to understand and ignore the rest.
Theme 3: The evolving emergent pattern	The evolvement from (a) input and (b) output of the cognitive process	(i). Hold a massive amount of evolving information	• The incoming information related to the issue in hand. • Difficulties to organise and stucture the information according to other expertise, level or depth and priorities. • The details is too much to handle. • They don't feel in-control on the uncertain of the information.
		(ii). Evolving information without groundings.	• Interchangeably words • Same idea but different wordings. Ideas just being rejected because they don't understand. • Not put in proper words – then the idea seems to be less valuable. • Group members reject the conceptual ideas if there is not yet detailed on it.
		(iii). Abstraction (divergence)	• Not put in proper words – then the idea seems to be less valuable. • Group members reject the conceptual ideas if there is not yet detailed on it.