THE DIFFERENTIATED FUNCTIONS OF SKETCH AND DIGITAL MODALITIES IN ARCHITECTURAL COLLABORATION DESIGN

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This thesis is dedicated;

I wish to dedicate this thesis to the development of Humanity, to my beloved mother Hajia Amina Mallam Adamu and my late father Alhaji Idi Danfulani (May his soul rest in peace, Amin.) Mom, Dad I ‘am so proud of you.

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ABSTRACT

Architectural collaboration is seen by many as an essential strategy that produces an outcome that is beyond individual vision. The majority of literature defines collaboration as two or more people sharing their differences constructively to search for a common goal. However, defining collaboration in the context of conceptual architectural design as two or more designers working together to achieve a common design goal appears to be very basic, as the definition does not in any way indicate how multiple designers can transform their tacit knowledge into an explicit building product. Instead, the definition undermines the rationale that collaboration can improve efficiency and effectiveness in sharing design ideas. This also implies that there is no clear understanding as to whether complex design activities such as actions, transformation, and reasoning can be readily circumscribed into collaborative settings. It presents one of the most significant challenges in realizing the much anticipated collaborative approach to design problem-solving. Therefore, there is a need to investigate key characteristics of collaboration in architectural design and their implications for the building development process. Thus this research aims to investigate the phenomenon of conceptual architectural collaboration design using the protocol study technique. The protocol consists of eight different design teams subjected to the usage of sketch modality to design a bus stand and a digital modality to design a commercial kiosk. A coding scheme based on design action, transformation, reasoning and knowledge transformation is employed to generate empirical data from the design protocol of the two modalities. Statistical analysis using Chi-Square cross tabulation has established a significant association between the two modalities and design activities. The results indicate that the design activities of the two modalities are statistically different concerning the distributed frequencies and duration of parameters of cognitive actions, tacit knowledge transformation, reasoning strategies and transformation. Higher framing action, abduction reasoning strategy and lateral transformation are not affected by the sketch modality but are affected by the change to the digital modality. Similarly, higher moving action, deduction reasoning strategy, and vertical transformation are not affected by the digital modality but are affected by the sketch modality. The correlation analysis of the sketch modality also established a significant relationship between parameters of tacit knowledge transformation, cognitive actions, reasoning strategies and design transformation. This findings provide answers to the types of modality that can influence or affect the process of socialization in the knowledge transformation during design collaboration. In conclusion, an integrated thinking pattern for conceptual architectural collaboration design is proposed.

ABSTRAK

Kerjasama dalam senibina dilihat oleh kebanyakan pihak sebagai strategi penting dalam menghasilkan dapatan di luar kotak fikiran individu. Kebanyakan kajian literatur mentakrifkan kerjasama sebagai dua atau lebih pereka yang bekerja bersama-sama untuk mencapai matlamat reka bentuk yang sama. Walau bagai mana pun definisi itu tidak menunjukkan bagaimana beberapa pereka dapat mengubah pengetahuan tersirat mereka menjadi hasil rekabentuk bangunan yang khusus. Sebaliknya, definisi itu menjejaskan rasional bahawa kerjasama boleh meningkatkan kecekapan dan keberkesanan semasa berkongsi idea reka bentuk. Ini juga menunjukkan bahawa tidak ada pemahaman yang jelas tentang apakah aktiviti reka bentuk kompleks seperti tindakan, transformasi, dan penaakulan dapat dibendung dengan mudah ke dalam tetapan kolaborasi. Ia menyajikan salah satu cabaran yang paling penting dalam merealisasikan pendekatan kolaborasi yang diharapkan untuk penyelesaian masalah rekabentuk. Oleh itu, terdapat keperluan untuk mengkaji ciri utama kerjasama dalam reka bentuk seni bina dan implikasinya dalam proses pembangunan bangunan. Oleh itu, kajian ini bertujuan untuk mengkaji fenomena reka bentuk kerjasama seni bina konseptual menggunakan teknik kajian protokol. Protokol ini terbahagi kepada 8 pasukan reka bentuk yang berbeza yang tertakluk kepada penggunaan modaliti lakaran untuk mereka bentuk pondok bas dan modaliti digital untuk mereka bentuk kiosk komersil. Sistem kod berdasarkan tindakan reka bentuk, transformasi, penaakulan dan transformasi pengetahuan digunakan untuk menghasilkan data empirikal dari protokol reka bentuk dua modaliti ini. Analisis statistik menggunakan taburan 'Chi – Square' telah mengesahkan satu persamaan penting antara dua modaliti dan aktiviti reka bentuk ini. Hasil kajian menunjukkan bahawa aktiviti reka bentuk kedua modaliti ini adalah berbeza secara statistik mengenai frekuensi yang diedarkan dan tempoh parameter tindakan kognitif transformasi tacit, strategi penaakulan dan trasformasi. Tindakan pembingkaian yang lebih tinggi, strategi pemikiran dan transformasi sisi tidak dipengaruhi oleh modaliti lakaran tetapi dipengaruhi oleh perubahan kepada modaliti digital. Begitu juga, tindakan bergerak yang lebih tinggi, strategi penaakulan dan trasformasi menegak tidak terjejas oleh modaliti digital tetapi dipengaruhi oleh modaliti lakaran. Analisis korelasi modaliti lakaran juga mengesahkan hubungan yang signifikan antara parameter transformasi pengetahuan tacit tindakan kognitif, strategi pemikiran dan transformasi reka bentuk. Dapatan ini memberi jawapan kepada hipotesis bahawa jenis modaliti boleh mempengaruhi atau menjejaskan proses sosialisasi dalam transformasi pengetahuan semasa kerjasama reka bentuk yang membawa kepada corak pemikiran bersepadu yang dicadangkan untuk reka bentuk kerjasama konseptual seni bina.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

2D	-	Two dimensional
3D	-	Three dimensional
ABD	-	Abduction
A-D-I	-	Abduction-deduction-induction
AI	-	Artificial intelligence
AIA	-	American institute of architects
BIM	-	Building information modeling
CA	-	Cognitive action
CAAD	-	Computer aided architectural design
CAD	-	Computer aided design
CHD	-	Center for Health Design
CITIS	-	Collaborative virtual organization
COM	-	Combination
CSCW	-	Computer supported collaborative works
D-E	-	Deduction-abduction
DED	-	Deduction
D-I	-	Deduction-induction
DIKW	-	Data, information, knowledge, wisdom
DSM	-	Distance shared media
DT	-	Design transformation
EBD	-	Evidence based design

EE	-	Explicit-explicit
ET	-	Explicit-tacit
EXT	-	Externalization
f	-	Frequencies
F2F	-	Face 2 face
FBS	-	Functional behavior structure
F-M	-	Framing-moving
F-R	-	Framing-reflecting
FRM	-	Framing
FTF	-	Face to face
HD	-	High definition
HVAC	-	High voltage air conditioning
ICT	-	Information communication technology
IDT	-	Immersive Discussion Tool
IFC	-	Industry Foundation Classes
IND	-	Induction
INT	-	Internalization
IPD	-	Integrated project delivery
I-S-E-C		Internalization-socialization-externalization-combination
KT	-	Knowledge transformation
LOD	-	Level of development
LSA	-	Latent semantic analysis
LTR	-	Lateral
MAVDCS	-	Multi-agent virtual design shared media system
MEP	-	Mechanical, electrical and plumbing
min	-	Minutes
MOV	-	Moving

NAM	-	Naming
NF	-	Naming-framing
N-F-M-R	-	Naming-framing-moving-reflecting
N-F-R-M	-	Framing-reflecting-moving
NVIVO	-	Analysis software
REF	-	Reflecting
RIBA	-	Royal institute of British architects
RS	-	Reasoning strategies
SECI	-	Socialization, externalization, combination and internalization
S-E-C-I	-	Socialization-externalization-combination-internalization
SOC	-	Socialization
SPSS	-	Statistics software
TE	-	Tacit-explicit
TT	-	Tacit-tacit
TUE	-	Technische Universiteit Eindhoven
TUI	-	Tangible user interface
UTM	-	Universiti teknologi Malaysia
VER	-	Vertical
VR	-	Virtual reality
VR3D	-	Virtual reality and three dimensional
VRML	-	Virtual reality modeling language

CHAPTER 1

INTRODUCTION

1.1 Introduction

The design may be described as a set of activities which are required in the development of a new product or service or system (Mosley et al., 2018). This involves a process of the mind which has been described by Schon (1983) as either reflection-in-action or reflection-on-action. Underpinning this description are complex concepts such as Linkography (Goldschmidt, 1995), function-behavior-structure (Gero, 1990), and frame-move-evaluation (Schon, 1983). In addition, Lawson (2004) has identified three major design processes which need to be considered and these are analysis, synthesis, and evaluation whereas, from a different point of view RIBA, (2013) point out that the key issues are conceptualization, development and technology.

According to Froese (2010) due to conditions associated with time, quality, cost and performance, the act of design is preferably better under a digital modality supported collaborative practice. Similarly, literature statistics have shown that adopting digital modality supported collaborative practice will vigorously remedy the profligacy of information, communication, resources and time facing the conventional design process (Garber, 2014; Bråthen, 2015; Luyten 2015).

However, due to the reflective nature of design, facilitating cognitive functions like actions, thinking, reasoning, sketching and visual transformation in a digital modality supported collaborative setting might imbue highly differentiated strategy, approach and modality. Therefore, the need to support cognitive design functions in a digital modality supported collaborative conceptual architectural design practice will be the focus area for this research.

1.2 Background to the Study

Two most distinctive characteristics of digital modality supported collaborative practice are focusing on a defined common goal that represents a collective input and output of all stakeholders and the challenge of managing team integration and dynamism (Stahl, 2006; Boud et al., 1999; Preece and Rombach, 1994; Huxham, 1996; Hord, 1986). Thus, the background study of digital modality supported collaborative practice in design should include a literature framework that explicitly define how can two or more designers achieve a defined common design goal that represents their collective input and output. Therefore, in the following paragraphs this research review relevant background literation on collaboration in the context design.

Sonnenwald (1996) explore on the role of collaboration in design. The study established that knowledge about communication support provides insight on the functionality of methods and tools of multidisciplinary design collaboration. In 1995, design studies journal organized a workshop on design teamwork involving a team of one designer (Dan) and a team of three designers (Ivan, John, and Kerry) where each team worked over a period of two hours. Using this same workshop data, Goldschmidt (1995) investigates the cognitive differences between the lone designer and the three-member design team in order to understand who does better in design. The study found that there is no significant difference between the individual and the team in the way they bring their work to fruition. Therefore, the study concludes that team size almost has no significant advantage over an individual when it comes to fulfillment of design.

Similarly, using the same workshop data, Cross and Cross (1995) employed protocol studies to investigate on the demonstration of the applicability of cognitive processes in design team practice. The study portrayed an understanding of the role and relationships of the design team based on planning, action, information sharing and gathering, analyzing and understanding of design problems. The study found that based on the social process, in design there is a significant interaction between the technical and cognitive process among designers in design teamwork.

Valkenburg and Dorst (1998) empirically identified and measured the structure of reflective practice of the design team. The study develops a pattern of reflective practice for a design team that indicates a differential pattern of behavior between teams based on naming, framing, moving and reflecting. The study has the only study that investigates the actual nature of design as shown in design theories in design teamwork. Chiu (2002) examined the organizational view of design communication in design collaboration. The study established that team organization in architectural design collaboration is better structured in practice than studios because design goal is more specific and often well defined in the architectural practice. Whereas, the study of Dong (2005) explored on communication and artifact knowledge construction of design team. The study established that similarities of language bridges indirect relations among designers mind which leads to a constructed shared mental representation of design artifacts. The study provides an initial background for understanding knowledge construction in design collaboration.

Stempfle and Badke-schaub (2002) investigate the thinking approach of the design team. The study distinguished between operations that serve to widen a problem space (generation, exploration) from operations that serve to narrow a problem space (comparison, selection) in design collaboration. Gabriel and Maher (2002) coded and modeled communication in architectural collaborative design to develop a coding scheme for the investigation of difference between computer-mediated collaborative design and face to face collaborative designs, to establish computer-mediated and communication tools for collaborative design. The study concludes that the nature of collaboration either computer-mediated collaborative design or face to face collaborative designs it does not make any significant difference in communication during the interaction.

Gül and Maher (2007) analyzed the impact of different settings on team design by comparing face-to-face sketching to designing in virtual environments collaborative design environments. The study concludes that changes in the design behavior can be categorized in two different ways: the effect of being in the same location and the effect of the type of external representations. Rahimian and Ibrahin (2011) discovered the differences between 3D and manual sketching techniques using protocol analysis of three peers of novice architectural designers. The study found that haptic-based design interface improved designers' cognitive and collaborative activities.

Testing of co-located and remote activities in virtual and face to face environment by Gu et al. (2011) indicated the potentials of three-dimensional virtual worlds against traditional co-located manual sketching and remote sketching using the smart board for supporting remote collaboration in design and tangible user interfaces (TUI) for enhancing co-located collaboration in design. Finally, the findings of the protocol analysis of four peers of professional architects for 3D world and three peers of second and third year architecture design students for TUI indicated that the three dimensional virtual worlds sufficiently support collaboration in design, whereas TUI session tend to establish more cognitive synchronization through active negotiation processes of three dimensional blocks where designers produced more perceptual activities. Ibrahim and Rahimian (2010) found that current conventional CAD tools are advantageous for detailed engineering design but, they hinder novice designers' creativity.

Mathew (2013) analyzed the potential of collaboration supporting technologies in a studio learning environment. The study provides evidence that supports the creation of a single digital building model by a student and group in a studio-based learning environment. Rahman et al. (2013) compared the effect of synchronous and asynchronous settings on team design process. The findings of the study provided clear indications that phase-specific usage of the shared object in the synchronous setting is better than the asynchronous settings. Feast (2012) determined the significance of teamwork in professional collaborative design work. The study concludes that the development of support for collaborative design should target not only problem-solving but also informal social interactions. Jutraz and Zupancic (2014) determine the importance of interdisciplinary collaborative design studios about whether architects learn anything new through interdisciplinary collaboration, and how such collaboration could be improved. The study found that it is important to incorporate interdisciplinary course for architecture students.

Based on extensive background study so far, it can be seen that most of the literature are found to have used protocol analysis method to investigate the role of technology, teamwork, communication and environment in a collaboration design setting. Whereas, issues like how to facilitate cognitive design functions like actions, thinking, reasoning, sketching and visual transformation in a digital modality supported collaborative settings fall short of proper investigation and explanation. Therefore, this thesis will focus on the subsequent problem emerging from the background study to pursue the context of the study.

1.3 Problem Statement

Digital modality supported collaborative practice is a means that encourage growth-oriented development associated with improving the efficiency of the architectural design process. Its application has been calculated by many literature statistics to have a significant impact on the quality, efficiency, and productivity of the design process (Azmi et al., 2018; Succar, 2009; Garber, 2014; Succar, 2009; Bryde et al., 2013; Lee, 2008). However, the issue of how the new approach can support the flexible nature of cognitive design functions like actions, thinking, reasoning, sketching and visual transformation is one of the emerging problem hindering its acceptance into a dominant silo conventional practice (Migilinskas et al., 2013).

Although, Jonson (2005) suggested that the future may offer a friendlier digital modality supported collaboration practice. Yet to date Jonson's suggestion have not been empirically supported.

Thus, the application of digital modality supported collaborative practice in design is a bit problematic, notably in the way, it can support cognitive design functions like actions, thinking, reasoning, sketching and visual transformation during conceptual architectural collaboration design. Therefore, this research problem statements reads as;

> ***"Digital modality supported collaborative practice need to support flexible cognitive functions during conceptual architectural collaboration design."***

1.4 Research Gap

Conceptual architectural design stage is a complex activity that involve highly human cognitive design functions like actions, thinking, reasoning, sketching and visual transformation (Valkenburg and Dorst, 1998; Dorst, 2011; Goel, 1994; Goldschmidt and Weil, 1998; Schon, 1983). In contrast, contemporary conditions promotes digital modality supported collaborative practice for the design, without explicitly establishing how multitude designers perform key human cognitive design functions like group actions, thinking, reasoning, sketching and visual transformation in a digital modality supported collaborative design environment (Vaishnavi and Kuechler, 2015; Preece et al., 2015; Hardin and McCool 2015; Kasali and Nersessian, 2015). To this end, this study proposes to investigate cognitive design functions during digital modality supported conceptual architectural collaboration design practice. These prompt to define the study research gap as:

“even though digital modality supported collaborative practice presumes improving the design, yet there is no clear theoretical or practical proving of how multitude designers perform key cognitive design activities like group actions, thinking, reasoning, sketching and visual transformation during conceptual architectural collaboration design (research gap).”

1.5 Research Aim

The aims to investigate conceptual architectural collaboration design and the implications of sketch and digital modalities.

1.6 Research Objectives

1. To propose the theoretical framework for collaboration in design.
2. To determine the impact of modalities on conceptual architectural collaboration design.
3. To establish the parameters of tacit knowledge transformation in conceptual architectural collaboration design.
4. To ascertain the relationship between knowledge transformation and productivity during conceptual architectural collaboration design.
5. To develop the pattern for conceptual architectural collaboration design.

1.7 Research Questions

1. What is the theoretical framework for collaboration in design?

2. What is the impact of modality on conceptual architectural collaboration design?
3. What are the parameters of tacit knowledge during conceptual architectural collaboration design?
4. Can knowledge transformation ascertain the productivity of collaboration during conceptual architectural collaboration design?
5. Is there pattern for conceptual architectural collaboration design?

1.8 Research Significance

Integrating the concept of digital modality supported collaboration in conceptual architectural design necessitates the invention of new theory as a contribution to the body of design knowledge in both architectural education and practice. This thesis will provide the parameters and pattern of the much anticipated conceptual architectural collaboration design.

1.9 Research Framework

The Data, Information, Knowledge, and Wisdom model (DIKW model) of hierarchical knowledge process (Ackoff, 1989) was adopted to frame the knowledge development process of this research investigation. According to Ackoff, the data is raw material that simply exists in any form or format and has no significance beyond its existence usability or not. The information is when the data has been given meaning by way of relational analysis or connection. This "meaning" can be useful, based on the rationale behind what data has been used. The knowledge is the appropriate understanding of the information, such that it becomes useful. Finally wisdom is a strictly human process that deals with moral and ethical codes that provide the understanding about which there has previously been no understanding, and in doing so, goes far beyond knowledge to become rather a human cognitive, philosophical probing (Ackoff, 1989).

Ackoff indicates that the first three categories relate to the past; they deal with what has been or what is known. Only the fourth category, wisdom, deals with the future because it incorporates vision. With wisdom, people can create the future rather than just grasp the present and past. However, achieving wisdom is not easy; people must move successively through the other categories. It can be noticed that the DIKW model prescribes a linear sequential hierarchy of knowledge processes. In reality, knowledge hierarchy can be iterative depending on the case under consideration. Nevertheless, the DIKW model is still used in many forms and shapes to look at the extraction of value and meaning of knowledge hierarchy. As shown in Figure 1.1 this study adopts the perspective of the DIKW knowledge hierarchy to frame the research.

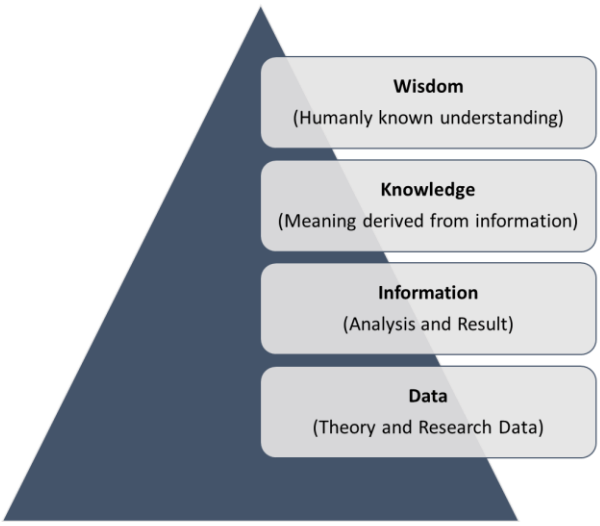

Figure 1.1: Research Framework (Ackoff, 1989 in Rowley, 2007, p.163)

In the context of this research, the data is framed as the literature review and records collected from our research measurements. The information is framed as the outcome results of the analysis of the research data. It is the transformation of the research data into a particular category of information that represents the initial requirement for the data gathering. Likewise, the next stage is knowledge which is framed as the useful meaning derived from the information which is significantly connected with the initial research problem, aim, objectives and questions.

However, at this stage, the knowledge cannot infer further understanding because it does not contain true cognitive and analytical ability that is only encompassed by a human which is contained in the next level of wisdom. The stage of wisdom is a frame that the understanding of the research topic or area has reached a stage whereby if questions are asked to which there is no humanly-known answer, wisdom can supply the answer. Therefore, it is the process by which I also discern, or judge, between right and wrong and good about conceptual architectural collaboration design. It is the unique state of understanding of the soul of conceptual architectural collaboration design. Thus, the structure of the DIKW is suitable to describe the research frame adopted for this thesis.

1.10 Research Methodology

In carrying out the research investigation, this study employs an empirically and contextually methodological choice known as mixed research method (Creswell, 2012). The method will use cross-sectional design experiment involving design teams solving a given design issue (Creswell, 2012). The cross-sectional experiment will offer the opportunity to investigate on what it takes to design while collaborating. Thus, from the perspective of the mixed research method the research philosophy, approach, time horizon and tactics are selected to satisfy the research aim and objectives. This research begins with establishing the fundamental framework of the integration of design and collaboration.

Similarly, the research approach is analysing, because the analysing research approach is not the conventional direct move from literature to data (as in deduction) or data to literature (as in induction), but rather a zigzag move between data-literature-data to establish that which is not yet known. It represents a value wanting to be achieved, as in this case designing while collaborating (Saunders et al., 2015). Interpretive research philosophy that entails a phenomenon is also suitable for the research. The interpretivism here implies the use of observation (Merriam and Tisdell, 2016).

1.11 Research Scope

This research is a driven from the theoretical perspective of the significant role of digital modality on. The research proceeds by identifying parameters for successful conceptual architectural collaboration design, before scoping to the research dependent, independent and controlled variables within the identified parameters. The study scope to a peer of unidisciplinary architectural design teams to control the effect clustering of morethan two multidisciplinary stakeholders in a single environment to talk about the same issue (known as team dynamics). Secondly, this research adopts LOD300 (level of development) of the digital modality scale to maintain the originality of the conceptual phase of the design and the capability of the modalities.

1.12 Research Overview

Through contextual and empirical investigation this research will attempt to define conceptual architectural collaboration design. Zooming from the perspective of Kan and Gero (2010) this research will use protocol analysis to carry out the study. One of the major motivating factors for the research is the postulation of Ho et al. (2013) that collaboration in design would serve as a better option that can promote better practice with rich problem-solving clues. Some other benefits also include supporting the transformation of conventional design practice into a more advanced technology guided practice. It can be noticed that research investigation on the concept of collaboration in design focusing on technology and environment has been taking place since the nineties.

However, such investigations focus mainly on collaborative technologies and environment (Wang et al., 2013; Xue et al., 2012; Gu et al., 2010). This can be due to the lack of relevant knowledge of how collaborative tools and environment to support design activities. Similarly, also there is the limited understanding of the actual impact such collaborative modalities can have on design. Thus, this research will investigate on what it means to collaborate while designing to advocate a differentiated understanding on how modalities can lead the way in providing the support for the actualization of effective conceptual architectural collaboration design.

1.13 Structure of Thesis

The structure of this thesis illustrated in Figure 1.2 explains the basic process from the start to the conclusion of the study. The major explanation is the understanding of what and how is a good integration of design and collaboration. What are the parameters required in achieving the stated objectives? Chapter 1 is the introductory chapter of the study which presents a summary of the research which is the overview and general foundation of the entire issue. The background further leads to the problem statements, research aim, question, and objectives.

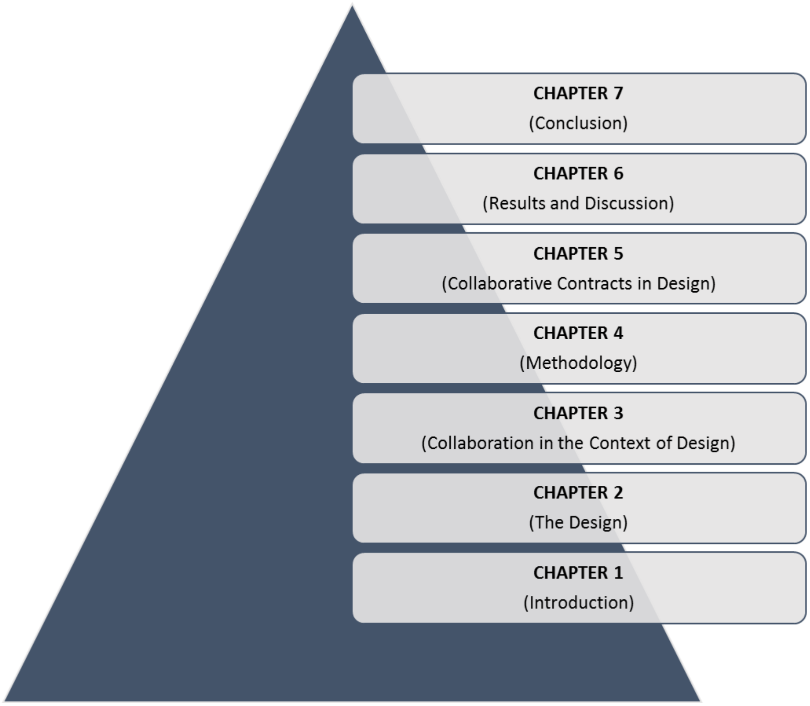

Figure 1.2: Structure of Thesis

Chapter 2 and 3 provides a theoretical background understanding of the integration of design and collaboration through an extensive review of current literature on both areas, some of which includes modalities. Furthermore, the chapter provides a theoretical understanding of the existing concept of conceptual architectural collaboration design through an extensive review of current literature research across the conventional and contemporary design process, some of which includes modalities.

Chapter 4 presents an overview of the methodology used to carry out the study. Here the actual structuring of the research method is carried out with a focus on the design process and collaboration, and critically discussing issues on research design, method, participants, sampling, and data. Finally, the chapter concludes with certain required factors for the data collection and also, describes the method used for the data collection, coding, and classification. The last part of the chapter explains the content of the data and explanation. The chapter indicates the core issues about the selection of the methodology and their relationship with the data.

Chapter 5 focuses on analysing the basic understanding and parameters of conceptual architectural collaboration design using protocol studies. The analysis was carried out with NVIVO, SPSS and Microsoft EXCEL software for data segmentation, coding, classification analysis and interpretation.

Chapter 6 deals with the results and discussion. The results and discussions are the useful information derived from the analysis. The chapter also presents the discussion of the result. The results derived from the analysis are used to generate some discussion which explains how the research question and objective are answered by the result. Therefore, this chapter provides answers to the research question in a discussion format.

Chapter 7 concludes the thesis by presenting answers and implications for further research. Finally, the thesis includes ten appendixes containing a sample of subjects, transcribed data, pictures coding, tabulation and publications.

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